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THE UNIVERSITY OF ALBERTA

INVESTIGATIONS OF ARTHROSIS IN GROWING MALE PIGS

by

© WALTER ROBERT PERRIN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Investigations of Arthrosis in Growing Male Pigs," submitted by Walter Robert Perrin, B.Sc (agr), in partial fulfilment of the requirements for the degree of Master of Science in Animal Nutrition.

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ABSTRACT

Experiments were conducted to investigate the incidence of leg weakness and arthrosis in male growing pigs. The objectives of the first experiment were to evaluate the effects of enforced exercise on the incidence and extent of leg and cartilage deformities of twelve growing male pigs. Eight boars were exercised on a treadmill, four at 2 km/h and four at 4 km/h, from a live weight of 22 to 90 kg. Pigs were exercised three days a week for a period of 60 min for each group; the remaining four boars acted as a control group. Blood serum samples, withdrawn at weeks 2, 6 and 10 of the experiment, were analyzed for chemical profile and protein electrophoresis. Animals were evaluated at weeks 6 and 10 by a team of three evaluators and the pigs were evaluated on leg appearance and mobility. Following slaughter of the pigs at 90 kg, legs were removed and the cartilage of major leg joints was evaluated for severity of visible lesions. Exercise treatments improved the appearance and mobility of legs, especially that of the front legs. There were no significant differences between the groups in severity of arthrotic lesions. Exercise treatment had no significant effect on feed intake, weight gain, efficiency of feed conversion, backfat, or loin muscle area. Changes that occurred in blood serum constituents between bleeding times were not

affected by exercise and were not correlated with the severity of lesions.

A second experiment was conducted to determine the weight or age at which lesions occurred in articular cartilage of boars, to examine the effects of a soft or hard floor on the incidence and severity of cartilage lesions and to examine any relationships that may exist between growth rate, blood serum chemical constituents, bone mineralization and the incidence and severity of cartilage lesions. Ninety-six boars, of two breeds, were killed at 3 days of age, shortly after weaning (43 days of age) and at 20, 40, 60, 80, 100 and 120 kg.

Visible cartilage lesions were observed in pigs killed after weaning and generally increased in incidence and severity with increasing weight of the pig. Most of the increased severity of lesions was observed after 60 kg live weight. Lesions were observed in the following decreasing incidence and severity: distal humerus, proximal femur > proximal radius-ulna, proximal humerus > distal radius-ulna, distal femur, proximal tibia and distal tibia. There were no significant differences between earth or concrete floor and between Yorkshire or crossbred pigs in the incidence or severity of arthrotic lesions.

Blood serum chemical changes; ash, calcium and phosphorus content of bone and growth rate were not significantly correlated with cartilage lesion severity.

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TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
REVIEW OF LITERATURE	3
Incidence of Locomotor Problems in the Pig	3
Etiology of Osteochondrosis and Arthrosis	6
Effects of sex	6
Effects of breed and genetics	7
Effects of nutrition	9
Effects of management	12
Pathogenic organisms	13
Skeletal and biochemical changes	14
EXPERIMENTAL INVESTIGATIONS	
PART I EFFECTS OF EXERCISE ON THE INCIDENCE OF LEG WEAKNESS AND ARTHROSIS	17
Introduction and Objectives	17
Materials and Methods	17
Blood serum analyses	20
Live animal appraisal	21
Cartilage and bone appraisal	22
Statistical methods	23
Results and Discussion	24
Feed intake, daily gain, efficiency of feed conversion, backfat and loin area	24
Live visual appraisal	26

PAGE

Cartilage and bone appraisal 29

Blood serum analyses 29

PART II INCIDENCE OF ARTHROSIS IN GROWING MALE PIGS SLAUGHTERED AT SUCCESSIVE STAGES OF GROWTH 36

Introduction and Objectives 36

Materials and Methods 37

Diets and pig weights 41

Blood serum analyses 41

Cartilage, bone appraisal and cartilage analyses 44

Methods of statistical analyses 44

Results and Discussion 47

Blood serum analyses 54

Appraisal of joint cartilage 59

GENERAL DISCUSSION AND SUMMARY 84

BIBLIOGRAPHY 88

APPENDIX A 100

LIST OF TABLES

TABLE		PAGE
1	FORMULATION AND COMPOSITION (AS FED BASIS) OF DIET IN EXERCISE EXPERIMENT	19
2	AVERAGE DAILY FEED (ADF), AVERAGE DAILY GAIN (ADG), EFFICIENCY OF FEED CONVERSION (EFC), ADJUSTED AVERAGE BACKFAT (ABF) AND ADJUSTED LOIN AREA (LA) FOR BOARS IN EXERCISE STUDY . .	25
3	MEAN SCORES FOR VISUAL APPRAISAL OF LEGS OF BOARS IN EXERCISE EXPERIMENT	27
4	MEAN LESION SCORES FOR APPRAISAL OF ARTICULAR CARTILAGE OF BOARS IN EXERCISE EXPERIMENT (WITH SITES COMBINED)	30
5	MEAN SCORES FOR APPRAISAL OF ARTICULAR CARTILAGE CONSIDERING SITES ON LEGS	31
6	CHEMICAL ANALYSIS OF RIGHT HUMERUS SHAFT AS INFLUENCED BY TREADMILL EXERCISE	32
7	BLOOD SERUM CALCIUM, INORGANIC P, ALK. P, GLUCOSE, CHOLESTEROL, LDH AND SGOT FOR BOARS IN EXERCISE EXPERIMENT	33
8	BLOOD SERUM BUN, TOTAL PROTEIN AND ELECTROPHORETIC COMPONENTS FOR SERUM PROTEIN OF BOARS IN EXERCISE EXPERIMENT	34

TABLE		PAGE
9	ALLOTMENT OF PIGS IN EACH REPLICATION TO TIME OR WEIGHT OF SLAUGHTER	38
10	NUMBER OF PIGS PER PEN AND FLOOR AREA PER PIG THROUGHOUT THE DURATION OF THE SERIAL SLAUGHTER EXPERIMENT	40
11	FORMULATION AND COMPOSITION (AS FED BASIS) OF STARTER DIET IN SERIAL SLAUGHTER EXPERIMENT .	42
12	FORMULATION AND COMPOSITION (AS FED BASIS) OF GROWER DIET IN SERIAL SLAUGHTER EXPERIMENT . .	43
13	PERFORMANCE OF PIGS ON A PEN BASIS FOR THE SIX GROWTH PHASES OF SERIAL SLAUGHTER	48
14a	AGE OF BOARS (DAYS) AT THE EIGHT SLAUGHTER TIMES	50
14b	DAYS ON TEST AND AVERAGE DAILY GAIN (ADG) OF BOARS FROM START OF TEST UNTIL SLAUGHTER . . .	51
15	TOTAL PROTEIN (T PROT), ALBUMIN (ALB), α-GLOBULIN (α-GLOB), β-GLOBULIN (β-GLOB), γ-GLOBULIN (γ-GLOB) AND BLOOD UREA NITROGEN (BUN) IN SERUM OF BOARS AT DIFFERENT SLAUGHTER TIMES AND WEIGHTS	55
16	CALCIUM, INORGANIC PHOSPHORUS (INORG P), ALKALINE PHOSPHATASE (ALK P), GLUCOSE, CHOLESTEROL, LACTATE DEHYDROGENASE (LDH), SERUM GLUTAMIC OXALOACETIC TRANSAMINASE (SGOT) IN BLOOD SERUM OF BOARS AT DIFFERENT SLAUGHTER TIMES	56

TABLE		PAGE
17a	PERCENTAGE INCIDENCE OF ARTHROSIS IN BOARS AT THE EIGHT SLAUGHTER WEIGHTS	62
17b	PERCENTAGE INCIDENCE, BY BREED, OF ARTHROSIS IN P.HUM, D.HUM, P.RAD AND P.FEM AT SEVEN SLAUGHTER WEIGHTS	64
17c	PERCENTAGE INCIDENCE, BY TREATMENT, OF ARTHROSIS IN P.HUM, D.HUM, P.RAD AND P.FEM AT SIX SLAUGHTER WEIGHTS	65
18a	MEAN CARTILAGE LESION SCORES FOR THE LEG JOINTS EXAMINED WITH RIGHT AND LEFT LEGS COMBINED . .	71
18b	MEAN CARTILAGE LESION SCORES FOR THE LEG JOINTS EXAMINED COMPARING RIGHT AND LEFT JOINTS . . .	72
19	CORRELATION COEFFICIENTS CALCULATED FOR CARTILAGE LESIONS AT JOINT SITES WITH OTHER JOINT SITES	75
20	MEAN CHEMICAL ANALYSIS FOR THE RIGHT HUMERUS SHAFT	77
21	CORRELATION COEFFICIENTS CALCULATED FOR RELATIONSHIP BETWEEN CARTILAGE LESION SCORES AND BONE MINERALIZATION	78
22	CORRELATION COEFFICIENTS FOR CARTILAGE LESION SCORES WITH BLOOD SERUM CONSTITUENTS	80
23	CORRELATION COEFFICIENTS FOR CARTILAGE LESION SCORES WITH AVERAGE DAILY GAIN	82

TABLE PAGE

APPENDIX

1 CORRELATION COEFFICEINTS FOR RELATIONSHIP BETWEEN LESION SCORE OF LEFT D.HUM AND BLOOD SERUM CONSTITUENTS OF BOARS IN EXERCISE EXPERIMENT 101

2 DISSECTION OF LEFT SIDE OF BOAR CARCASS INTO MUSCLE + FAT AND BONE AT EIGHT WEIGHT GROUPS 102

3 PROXIMATE ANALYSIS OF MUSCLE + FAT FROM THE LEFT SIDE OF BOARS AT EIGHT WEIGHT GROUPS . . 104

LIST OF FIGURES

FIGURE		PAGE
1	Percentage incidence of arthrosis in the distal humerus of boars at eight slaughter weights	67
2	Percentage incidence of arthrosis in the proximal femur of boars at eight slaughter weights	68
3	Mean lesion scores of the distal humerus of boars from weaning to 120 kg	73
4	Mean lesion scores of the proximal femur of boars from weaning to 120 kg	74

LIST OF PLATES

PLATE		PAGE
1	Proximal humerus of a pig. The cartilage surface is rough and shows "wear grooves".	60
2	Split, separated cartilage with collapsed subchondral bone tissue in the medial condyle of the humerus of a pig	60
3	Femoral head of a pig showing flattened appearance and evidence of collapse of subchondral bone	61
4	Femoral head of a pig showing "wear grooves" on right side of bone	61
5	Distal humerus of a pig. Cartilage appears thin, red and rough	66
6	Elbow joint of a pig. Cartilage on both surfaces is split and separated with collapsed subchondral bone tissue	66

INTRODUCTION

Performance testing is an essential feature of any genetic improvement program with livestock. Considerable progress has been made in developing test procedures to provide genetically meaningful performance comparisons of swine breeding stock. One of the major reasons for the rejection of boars on the Canadian Record of Performance for Swine Program is a high incidence of locomotor problems. These locomotor problems involve a variety of defects in the shape, posture and function of the fore legs and hind legs of pigs.

The cause or causes of these locomotor disturbances have not been clearly established. The appetite of affected pigs is not usually altered and pain does not seem to be a dominant feature of the condition; however, performance of affected pigs may be reduced, especially in the later stages of growth. More important, the numbers of animals from which to select breeding stock are drastically reduced since pigs of both high and low genetic merit seem to be equally affected.

Accompanying the clinical condition of "leg weakness" are a variety of lesions of articular cartilage and bone which are thought to be the major causes for changes that occur in the shape of legs.

Researchers in various countries have studied several aspects of the problem described above, however, no definite conclusions have been drawn with regards to the time of occurrence of the first lesions of cartilage and bone, possible metabolic changes associated with the condition, causes of the condition, and thus a potential solution to the problem.

The investigations reported herein are part of a larger study at The University of Alberta to examine the age or weight of occurrence of cartilage lesions both visually after dissection and histologically, to determine any blood serum and biochemical cartilage changes that may be associated with cartilage lesions and to examine carcass growth patterns that may be associated with occurrence of lesions in cartilage and bone.

REVIEW OF LITERATURE

Incidence of Locomotor Problems in the Pig

The incidence of joint and bone lesions in pigs has been investigated in a number of countries during the last 20 years. In Sweden, Christensen (1953) described the occurrence of pronounced changes in the larger joints of both fore and hind legs of Landrace boars at 9 months and older. The most common lesion was a deformity of the head of the femur with a more or less pronounced crest against the neck and degeneration of the cartilage. No evidence of rickets was found. Bacteriological examinations of the joint capsules were negative. In England, Thurley (1965) described three types of joint cartilage changes: (1) Wear lesions with thin cartilage and no reaction of the subchondral bone tissue in the early stages. These lesions were most often demonstrated on the head of the femur and the head of the humerus, (2) Proliferative lesions with collapse of the subchondral bone tissue and formation of so-called "brood capsules" in the cartilage. These lesions were most often demonstrated in the condyles, and the head of the femur, and (3) Lift lesions in which the cartilage was detached from the subchondral bone tissue. These lesions were most often found in the semilunar notch of the elbow joint.

Duthie and Lancaster (1964) in England, as a result of a field survey, concluded that leg weakness occurred quite commonly in commercial swine herds in that country. Lesions of synovia of joint capsules and articular cartilages of limbs were found which were considered to be major causes of the clinical signs of leg weakness.

Walker et al. (1966), also from England, described a special lesion of the distal epiphyseal plate of the ulna. Three main types of lesions were observed with patho-anatomical study: (1) The lesion in cartilage, (2) The lesion in the zone of provisional calcification, and (3) The process of repair.

Histological examinations of epiphyseal cartilage from 36 clinically normal pigs and 13 pigs with leg weakness were conducted by Thurley (1969). The animals were between 47 and 160 days old and of varying breed. Both males and females were included in the study. He frequently demonstrated in both groups the occurrence of the following deviations from the normal; (1) eosinophilic streaking, (2) eosinophilic patches, (3) local irregularity of the length of columns of cartilage cells, (4) endochondral osseus dysplasia, and (5) aberrations in the direction of the columns of cartilage cells.

Fell et al. (1970) reported that between 76 and 88 percent of ulnae and humerii from 136 pigs had radiological and histological lesions in the distal epiphyseal growth

plates and in the metaphyses even though very few of the pigs were noted as being clinically affected by leg weakness.

Ljunggren and Reiland (1970) demonstrated degenerative joint lesion, mainly localized to the large diarthrodial joints, in 80 percent of 250 pigs. Infoldings and erosions in the joint cartilage were noted symetrically with respect to right and left legs. Lesions in the growth plate were also noted. Histological examination of early cases revealed degenerative processes in the basal zone of the thickened joint cartilage. In the more advanced stages, fissures and clefts occurred in the cartilage. The condition led to disturbed endochondral ossification. The authors suggested using the term osteochondrosis to describe these lesions. The term osteochondrosis is also used in human medicine to describe a similar condition in which an ossification center, expecially in the epiphyses of long bones undergoes degeneration followed by calcification.

In Canada, cartilage lesions were present in nearly all of the elbow joints of forty-eight boars (Bowland et al. 1973). Moderate to severe lesions were observed in 64 percent of the pigs and lesions occurred symetrically with respect to right and left legs. On a live animal visual appraisal, 58 percent were judged affected by lameness while 40 percent were judged moderately to severely affected by lameness in the forelegs. Hind legs were not affected as often or as

severely by lameness as the fore legs.

Lesions of varying degrees of severity in most pigs at 90-100 kg live weight were demonstrated by Grondalen (1974a). He found that the typical osteochondral lesions were most often symmetrical, occurred at certain sites in joints and epiphyseal plates and were most obvious in the elbow and stifle joint, and in the distal epiphyseal plate of the ulna.

Grondalen (1974a) also investigated early changes in the medial condyle of the femur and his results suggest that primary changes occur early in the deep layer of the cartilage and that changes in the bone tissue and the superficial layer of the cartilage are secondary. In his investigation, 10 percent of 10 to 20 kg pigs were affected with osteochondrosis in the medial condyle of the femur. At 50 to 80 kg liveweight, 77.8 percent of the pigs were affected, some with lesions of the superficial layers of cartilage. He used the term arthrosis as a name for lesions affecting the joint cartilage.

Etiology of Osteochondrosis and Arthrosis

The etiology of osteochondrosis and arthrosis has not yet been clearly determined and a complex combination of factors appear to be involved.

Effects of sex. It has generally been observed that "leg weakness" and the lesions in articular cartilage

associated with it have occurred more often in growing boars than in gilts or castrates (Walker et al. 1966). However, Fell et al. (1970) found that there was no difference in the incidence or severity of radiological and histological lesions in the ulnae or humeri of boars, gilts, or castrates.

Effects of breed and genetics. Duthie and Lancaster (1964), as a result of a field survey which showed that several breeds of pigs were affected by "leg weakness", suggested that breed and genetics were not major factors contributing to the incidence of articular cartilage lesions.

The incidence of osteochondrosis and arthrosis in young animals of the Norwegian Landrace and Yorkshire breeds was compared by Grondalen (1974c). All animals were bred under the same conditions of feeding and housing. In general, Yorkshire pigs showed a lower incidence and a less marked degree of osteochondrosis and arthrosis than Landrace pigs. The Landrace pigs had longer bodies, broader hindquarters, shorter femurs, and the stifle had a different shape as compared with the Yorkshire pigs. Grondalen concluded that there was a connection between exterior features, joint and bone shape and the occurrence of joint lesions.

Grondalen and Vangen (1974) compared the incidence of osteochondrosis and arthrosis in three different lines

of the Norwegian Landrace breed. Investigations were carried out on 289 slaughter pigs, 56 breeding boars, and 51 breeding sows in a selection experiment. The animals investigated belonged to the fourth to sixth generations of the selection experiment. One line had been selected for thin backfat and rapid growth (LBL) and one for thick backfat and slow growth (HBL). In addition a control line (CL) not subjected to selection was maintained. The skeleton, measured as the length of bones and vertebral column, was significantly shorter ($P < 0.01$) in HBL than in CL and LBL. There was a lower incidence and significantly ($P < 0.01$) lower degree of total lesions in joints and bones in HBL, with regards to slaughter pigs, boars and sows. The lumbar region of the vertebral column consistently showed the greatest difference in degree and incidence of lesions between the genetic populations and the authors suggest that this becomes the weakest skeletal part in pigs with a rapidly growing skeleton.

Other investigators (Fell et al. 1970) concluded that there were no differences between sire groups in the incidence and severity of radiological and histological lesions of ulnae and humeri. In their experiment, 136 Large White pigs from six sires were investigtated.

Smith (1966) attempted to calculate a heritability value for leg weakness using "leg weakness" scores for pigs from pig progeny testing stations in Britain. Large White

and Landrace pigs were involved in the study. Heritability estimates were calculated using three different methods. All three methods gave very low heritability values and it would seem that a decrease in the amount of leg weakness in pigs would be slow and difficult to achieve by genetic selection against the condition. Teuscher et al. (1972) estimated a heritability value for leg weakness of 0.5-0.6, but they thought that the value was an overestimate. Their value was considerably higher than any of the values calculated by Smith (1966).

Effects of nutrition. The interactions of calcium, phosphorus and vitamin D was historically one of the earliest nutritional causes of bone disease to be investigated. Therefore, it is one of the first diseases thought of when lameness occurs in growing pigs.

The National Research Council (N.R.C., 1973) lists dietary calcium requirements of 0.65 and 0.50 percent, respectively, for growing pigs of 10-35 kg body weight and for pigs from 35-100 kg body weight; phosphorus requirements of 0.50 and 0.40 percent respectively, for the above weight groups of pigs and vitamin D requirements of 200 and 125 I.U. per kg of diet, respectively, for the same weight groups of pigs. Maintaining the above levels in a ration should provide for adequate bone mineralization to prevent rickets and lameness.

Duthie and Lancaster (1964) conducted several trials to determine if there was any relationship between the levels of calcium and phosphorus in the diet and the incidence of "leg weakness" in pigs. In one trial they compared four feeds containing 0.6, 0.9, 1.0, and 1.2 percent, respectively, of calcium and 0.6, 0.8, 1.0 and 1.2 percent respectively, of phosphorus. There was no relationship between level of calcium and phosphorus and the incidence of leg weakness. The same authors conducted another experiment with 0.50, 1.0, and 1.0 percent of calcium and 0.50, 0.50, and 0.80 percent of phosphorus in three rations fed to pigs during the growing period. They found no relationships between those treatments and the incidence of leg weakness and the lesions associated with the syndrome.

The observations of Duthie and Lancaster (1964) were confirmed by Walker et al. (1966). Varying the calcium, phosphorus or vitamin D concentrations and the calcium: phorphorus ratio did not affect either the incidence or severity of joint lesions or the clinical signs of leg weakness.

Neher et al. (1956) found lesions in the ulnae of pigs given a diet deficient in managanese but not in two pigs given a diet containing about 44 p.p.m. manganese. Walker et al. (1966) reported that they observed the typical ulnar lesions in boars given diets containing up to

142 p.p.m. manganese. These results show that a dietary deficiency of manganese is not likely the cause of ulnar lesions. The diets used by Walker et al. (1966) contained supplemental copper, probably ruling out copper deficiency as a possible cause of the lesions in the ulna.

The addition of 0.27 percent calcium and 0.20 percent phosphorus to a diet containing 0.80 percent each of calcium and phosphorus did not have any major influence on the incidence or severity of leg weakness or cartilage lesions of boars in an ROP test station (Bowland et al. 1973). Increasing the level of manganese from 93 mg to 170 mg per kg of diet had no influence on leg unsoundness; the addition of calcium, phosphorus and manganese together had no influence either.

According to Walker et al. (1966), the addition of vitamin C to rations did not prevent the onset of the ulnar lesions and they found the vitamin C status of affected animals to be satisfactory, as assessed by blood plasma ascorbic acid concentrations and the urinary excretion of ascorbic acid. Walker et al. (1966) also stated that the vitamin A status of affected animals appeared to be satisfactory as judged by the high concentrations of the vitamin in the liver of a number of boars suffering from leg weakness and showing the ulnar lesions.

Rate of growth as influenced by nutrient density and daily consumption of food has been suggested as a factor

affecting the incidence of leg weakness and cartilage lesions. Duthie and Lancaster (1964) or Fell et al. (1970) were not able to show that the incidence and severity of lesions associated with leg weakness were related to fast growth rate of the pigs.

Effects of management. Lameness in swine has been attributed to a lack of adequate exercise under confinement rearing (Neher 1964). Elliot and Doige (1973) found that individual penning of growing pigs in 0.6 x 1.2 m pens results in more locomotor problems than in pigs penned in groups of four with approximately the same floor area per pig. Individual penning resulted in a reduced ($P < 0.01$) cross-sectional area of cortical bone and a decreased ($P < 0.01$) breaking strength of bone in comparison with group penned animals. The authors considered the results to be primarily the result of muscular weakness or a lack of muscle tone attributable to a lack of normal exercise. Thurley (1971) also states that there may be an association between degenerative joint lesions and muscular weakness.

The observation of Duthie and Lancaster (1964) that the general husbandry and health of pigs were better than usual on farms where leg weakness occurred with a high frequency indicates that there may be some relationship of leg weakness to intensive management.

Vaughan (1971) suggests that softer flooring such as grass and earth provides a more secure footing than does slippery concrete for limbs with defective posture and may prevent severe clinical lameness. No reports of investigations examining the effect of type of floor on the incidence of leg weakness were found in the literature.

Pathogenic organisms. Arthritic conditions and lameness in swine can be caused by bacteria, mycoplasma or harmful immunologic reactions. Duthie and Lancaster (1964) believed that infectious osteoarthritis was the major cause of clinical lameness in the pigs they investigated with leg weakness, even though they were unable to isolate any organisms during bacteriological examinations.

Pleuropneumonia-like organisms (PPLO) have been shown to cause a polyarthritis of pigs (Heinze et al. 1963). Inflammatory and proliferative changes of the synovial membrane are characteristic but articular cartilages are not apparently involved in PPLO arthritic conditions.

Collins and Goldie (1940) and Hughes (1955) described a chronic polyarthritis of pigs induced experimentally by E. rhusiopathiae, and they demonstrated that this arthritis was not preceded by signs of acute or subacute swine erysipelas but only by trivial skin or temperature reactions.

Roberts et al. (1963) described spectacular arthritis associated with Mycoplasma hyorhinis. Acute changes occurred in the synovial membrane which consisted mostly of a

yellowish discoloration. Some changes occurred in the epiphyseal plate of some bones, characterized by disorganization of the orderly maturation of cartilage cells.

The cartilage lesions occurring with leg weakness are usually localized and not general in nature and most researchers have concluded that infectious agents are not the cause. Walker et al. (1966), Grondalen (1974a, 1974b, 1974c, 1974d) and other workers have been unable to find any organisms associated with affected joints that may contribute to such a condition.

Skeletal and biochemical changes. Thurley (1965) suggests that a rapidly grown pig may have less bone and thinner muscle fibres than a slower grown littermate and that the small amount of exercise allowed in confinement may contribute to leg weakness. Schilling, as quoted in Thurley (1965), believes that changes in the angles of attachment of muscles and changes in the angles of joints to accommodate greater masses of muscle contribute to the production of arthropathy.

Experiments by Grondalen (1974c) support the above statements. He showed skeletal changes that were associated with the incidence of osteochondrosis and arthrosis in his studies. It was found that longer bodies, broader hind-quarters, shorter femurs, and a different shaped pelvis of the Norwegian Landrace breed as compared with Yorkshire pigs contributed to the incidence of cartilage and bone lesions in

the former breed.

Abnormal physical forces on some parts of the skeleton contribute to the production of bone and cartilage lesions. Both Walker et al. (1966) and Grondalen and Grondalen (1974) produced reversible ulna lesions by overloading or fixing one or more of the front legs. In those trials, the epiphyseal blood supply seemed to be affected by the overloading.

Weiss et al. (1973) studied leg weakness and associated blood, bone and muscle biochemical parameters and found no changes in blood protein or electrolyte content of serum and bone associated with leg weakness. Postmortem meat studies revealed no association of muscle pH or incidence of pale, soft exudative muscle with the leg weakness condition.

Simunek and Muir (1972) found no overall changes in composition when comparing knee joint cartilage of lame and normal animals. They reported that the proteoglycans in the cartilage of the lame pigs were extracted more easily by a standardized sequential procedure and contained a higher proportion of molecules of smaller size as assessed by gel chromatography. The differences between normal and lame groups were greater at 10 weeks than at 25 weeks of age, and the authors speculated that rapid weight gain may be too great for the immature cartilage to bear. They didn't establish whether the changes in proteoglycans were as

a result of proteolytic degradation or were as a result of biosynthetic failure.

The above review indicates that the leg weakness syndrome in pigs causes considerable loss of potential breeding stock from the swine industry. The condition is of complex etiology and requires research to establish solutions to the problem.

EXPERIMENTAL INVESTIGATIONS

PART I

EFFECTS OF EXERCISE ON THE INCIDENCE OF LEG WEAKNESS AND ARTHROSIS

Introduction and Objectives

Lack of normal movement may lead to degenerative changes in bone joint cartilage (Evans et al. 1960). It is recognized that cartilage receives its nourishment by diffusion and imbibition of the surrounding fluids and that intermittent compression of the cartilage during movement is important in bringing mutritive joint fluids to the chondrocytes of cartilage (Trias, 1961). Lack of exercise in confinement housing has been implicated as a factor contributing to leg weakness in pigs (Elliot and Doige, 1973).

The objectives of this study were to evaluate the effects of enforced exercise on the incidence and extent of leg and cartilage deformities of growing male pigs and to examine blood chemical constituent changes that may be associated with the incidence of leg weakness.

Materials and Methods

Twelve male pigs were used in the experiment. Six animals were selected, three from each of two crossbred litters from The University of Alberta Swine Research Unit.

Six Lacombe pigs were also selected, three from each of two litters. The Lacombe boars were purchased from a private breeder. The pigs were allotted to three treatments, one pig from each litter per treatment. Treatments consisted of a control without enforced exercise, one group exercised at 2 km/h (LE), and another group exercised at 4 km/h (HE). The pigs were allotted at an average weight of 22.3 kg and were housed in individual pens (2.0 x 0.4 m) with water available ad libitum. They were housed on a concrete floor and no bedding was used. Cleaning of pens was practiced daily by flushing material into a drain with water. Temperature of the room was maintained at 20°C for the duration of the experiment. The pigs were fed a pelleted growing ration ad libitum similar to that used in the Canadian Record of Performance for Swine Program (Table 1). During time of exercise, all boars including those in the control group were denied access to feed and water. Pigs from all groups were weighed bi-weekly until the heaviest pig reached 80 kg and then weekly thereafter until the end of the experiment.

The control group boars were confined to their pens except when they were moved to the scales for weighing. Both groups of pigs on exercise were subjected to enforced exercise on a treadmill at 0 slope from time of allotment to the experiment until they reached 90 kg. Pigs were exercised on Monday, Wednesday and Friday by tethering them inside a divided wooden and metal frame superimposed on the

TABLE 1

FORMULATION AND COMPOSITION (AS FED BASIS) OF DIET IN EXERCISE EXPERIMENT

Ingredients %	
Barley	52.0
Wheat	26.5
Soybean meal (48.5% protein)	12.5
Fishmeal (70% protein)	2.5
Stabilized tallow	2.5
Salt (iodized)	0.5
Limestone	0.5
Dicalcium phosphate	2.0
Trace mineral mix[1]	0.5
Vitamin mix and zinc bacitracin[2]	0.5
Composition (by analysis)	
Crude protein (%)	16.2
Gross energy (kcal/kg)	3718
Calcium (%)	0.99
Phosphorus (%)	0.80

[1]The trace mineral mix supplied the following per 100 kg diet: 8.80 g manganese; 7.04 g iron; 2.20 g copper; 10.12 g zinc, 22 mg iodine.

[2]The vitamin mix supplied the following per 100 kg diet: 330,000 IU vitamin A; 33,000 IU vitamin D; 1100 IU vitamin E; 440 mg riboflavin; 1980 mg niacin; 880 mg calcium pantothenate; 55 mg folacin; 11 mg biotin; 2.0 mg vitamin B_{12}; 1.10 g zinc bacitracin.

treadmill. Leather collars were fitted to all pigs to facilitate tethering them. For the first week, the duration of exercise was three 10-min periods daily at 2 km/h for the low exercise (LE) and at 4 km/h for the high exercise (HE) group with alternate rest periods of 10 min. Thereafter, the exercise was increased on subsequent weeks by 10-min periods until the pigs were exercised for six 10-min periods each day with intervening rest periods of 10 min.

Blood serum analyses. Blood samples were collected from each boar by anterior vena cava puncture (Carle and Dewhirst, 1942) at the second, sixth and tenth week of the experiment. Animals were not deprived of feed or water immediately prior to collection of blood samples, so that blood serum constituents are on a non-fasting basis. Blood was collected on a day when the exercise groups were not being exercised. Blood was collected into vacutainer tubes, centrifuged to separate the serum, and serum profile analysis was performed by Dr. S. Hanson and Associates, Medical Laboratory, 10830 Jasper Avenue, Edmonton, Alberta using the Technicon SMA 12/60 Autoanalyzer.[1] Serum samples were analyzed for the following:

(1) Calcium - calcium concentration (mg/100 ml serum) was determined using a method reported by Gitelman (1967).

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[1]Technicon Instruments Corporation, Tarrytown, New York 10591. U.S.A.

(2) Phosphorus - inorganic phosphorus concentration (mg/100 ml serum) was determined by the method of Hurst (1964) as adapted to the Auto Analyzer by Kraml (1966).

(3) Glucose - glucose concentration (mg/100 ml serum) was determined by a modification of the procedures of Brown (1961) and Bittner and McCleary (1963).

(4) Blood Urea Nitrogen (BUN) - BUN concentration (mg/100 ml serum) was determined by a modification of the method of Marsh et al. (1965).

(5) Cholesterol - cholesterol concentration (mg/100 ml serum) was based on a modification (Huang et al. 1961) of the Lieberman-Burchard reaction.

(6) Alkaline phosphatase (Alk. P) - Alk. P (mU/ml) was determined by the method of Morgenstern et al. (1965).

(7) Lactate Dehydrogenase (LDH)- LDH (mU/ml) was based on the procedure of Hochella and Weinhouse (1965).

(8) Serum Glutamic Oxaloacetic Transaminase (SGOT) - SGOT (mU/ml) was based on the procedure of Morgenstern et al. (1966).

Serum proteins (gm/100 ml) were also analyzed by Dr. S. Hanson and Associates using a microelectro-phoresis technique on cellulose acetate (Grumbaum et al. 1963) to measure total protein, albumin, alpha 1-globulin, alpha - 2-globulin, beta globulin and gamma globulin.

Live animal appraisal. Visual appraisal of the feet and legs of the pigs was made by three appraisers at the

sixth and again at the tenth week of test. The appraisers independently scored all pigs for equal or different size toes and for leg conformation and gait. Leg conformation and gait were scored on a scale from 0 to 4 with 0 being normal and 4 assigned to boars showing severe crippling. All legs and toes were assigned individual scores.

Backfat thickness and loin muscle area measurements were made on each pig as it approached slaughter weight, using an ultrasonic probe (Krautkramer Ultrasonic Flaw Detector, type U.S.M. 2). Four backfat measurements were made and the mean backfat thickness was derived from the average of the four sites measured. The measurement sites were at the last rib at 5 cm on both sides of the dorsal medial line and 15 cm posterior to the above two sites. Mean loin muscle area measurements were derived from the average of two sites measured, at the last rib at 5 cm on both sides of the dorsal medial line.

Cartilage and bone appraisal. The animals were killed by mechanical stunning when they reached 90 kg live weight. Following slaughter, all four legs were immediately dissected out to examine major limb joints and articular cartilage. The articular cartilage on the acetabulum, proximal femur, distal femur, proximal tibia and fibula and distal tibia and fibula of the hind legs and the articular cartilage on the scapula, proximal humerus, distal humerus,

proximal radius and ulna, and distal radius and ulna of the fore legs were examined visually and subjectively evaluated according to the following scale:

0 - normal, clear and smooth

1 - slight irregulartiies or slightly red and thin

2 - small abrasions and slight lesions present

3 - cartilage lifting or severe lesion present

4 - cartilage severely damaged

The humerus bone from the right leg was selected for chemical analysis to determine the ash, calcium and phorphorus contents of the skeletal structure. The bone shaft between the epiphyseal plates was cut into discs and then freeze dried[2] (38 C shelf temperature for 72 h). The bones were then crushed in a steel mortar and pestle similar to the design described by Aeschbacher and Brown (1972), extracted with petroleum ether to remove the fat and given a final grinding through a Thomas sample grinder[3] using a No. 20 screen. The resulting finely ground bone was analyzed for ash, calcium and phosphorus (A.O.A.C., 1970),

Statistical methods. Analyses of variance were performed on the data collected to determine whether significant differences existed. Sources of variation for the

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[2]Repp Sublimator, Model SRC 42. Division of Virtis Co. Inc.: Gardiner, N.Y. 12525, U.S.A.

[3]Thomas sample grinder, Arthur H. Thomas Co., Philadelphia, Pa., U.S.A.

growth, feed, backfat and bone chemical analysis data were treatments (N = 3) and pigs within treatments (N = 4). For the live visual appraisal there were also evaluators (N = 3) and times (N = 2). Therefore, sources of variation for live visual approasal were treatment (N = 3), evaluators (N = 3), times (N = 2) and pigs within treatments (N = 4). Sources of variation for blood serum analysis were treatment (N = 3), times (N = 3) and pigs within treatments (N = 4). Sources of variation for cartilage lesion score were treatment (N = 3), pigs within treatments (N = 4), right and left legs (N = 2), front and back legs (N = 2) and sites within front and back (N = 5). Mean differences were detected using the F - Test (Steel and Torrie, 1960). Notations used to indicate level of signficance are: *($P < 0.05$), **($P < 0.01$), ***($P < 0.001$). There were some missing values for blood analyses data and these values were estimated using a multiple factor Analysis of Covariance program. To calculate error mean squre, 1 degree of freedom was subtracted for each value missing. Multiple comparison of means was made ($P < 0.05$) using Duncan's Multiple Range Test (Steel and Torrie, 1960) and means not significantly different bear the same letter or no letter.

Results and Discussion

Feed intake, daily gain, efficiency of feed conversion, backfat, and loin area (Table 2). There were no significant differences between the daily feed intake of the Control, LE

TABLE 2

AVERAGE DAILY FEED (ADF), AVERAGE DAILY GAIN (ADG), EFFICIENCY OF FEED CONVERSION (EFC), ADJUSTED AVERAGE BACKFAT (ABF) AND ADJUSTED LOIN AREA (LA) FOR BOARS IN EXERCISE STUDY

Treatment	1 Control	2 LE	3 HE	Grand Mean	Standard Error of Mean
ADF (kg/day)	2.32	2.21	2.28	2.27	0.22
ADG (kg/day)	0.77	0.78	0.68	0.74	0.09
EFC (kg feed/ kg gain)	3.35	2.79	3.44	3.19	0.41
ABF (mm)	16.7	16.8	15.2	16.2	1.87
LA (cm^2)	35.6	34.0	35.0	34.8	1.49

In subsequent tables, SE will signify Standard Error of Mean for Treatment.

or HE pigs. Similarly, the average daily gain of the three groups was not different although HE gained 0.68 kg per day compared with 0.77 and 0.78 kg per day for control and LE respectively. No significant differences in efficiency of feed conversion existed between the groups, although efficiency of feed conversion of 2.79 kg feed/kg gain for LE appeared better than 3.35 and 3.44 kg feed/kg gain of Control and HE respectively.

The average backfat of 16.7, 16.8 and 15.2 mm for the Control, LE and HE groups, respectively were not significantly different, although the HE had slightly less backfat than Control or LE groups. Loin muscle area measurements of 35.6, 34.0, 35.0 cm^2 for the Control, LE and HE groups, respectively were not different from each other.

These results suggest that the exercise imposed on the pigs did not have a major influence on energy expenditure and hence on feed intake, gain, efficiency of feed conversion, backfat and loin area measurements. Murray et al. (1974) made similar observations when pigs were exercised at 2 km/h.

Live visual appraisal. Table 3 summarizes the visual appraisal scoring for leg conformation and gait. Front legs of pigs not exercised showed more abnormalities, such as bowleg and flexion of the carpus, than hind legs of the same pigs and were significantly worse ($P < 0.05$) than pigs in LE or HE for front leg scores. There were no

TABLE 3

MEAN SCORES FOR VISUAL APPRAISAL OF LEGS OF BOARS IN EXERCISE EXPERIMENT

	Subjective Score					
	Front Legs vs. Hind Legs		Right Legs vs. Left Legs		Week 6 vs. Week 10	
Control	1.58b	0.60a	1.13d	1.06cd	0.71ab	1.47c
LE	0.75a	0.81a	0.67b	0.90c	0.54ab	1.02bc
HE	0.54a	0.33a	0.38a	0.50ab	0.19a	0.69ab
SE	0.17		0.06		0.22	

differences between any of the treatments in the hind leg scores. Observations of abnormalities in the hind legs were most often sickle legs and bow legs. The left legs of pigs in LE were affected more ($P < 0.05$) than right legs; however, in the other two treatments there were no significant differences between left and right legs in appraisal score, although the left legs of HE pigs had a mean score of 0.50 compared with 0.38 for the right legs. There is no obvious explanation for any differences occurring between left and right legs in severity of leg weakness and the differences observed here may be as a result of the few numbers of pigs involved. Exercise improved the appearance of both right and left legs. Considering the right legs, the HE group was less affected ($P < 0.05$) than LE and LE group was less affected ($P < 0.$[illegible]) than Control. When considering the left legs HE pigs had lower scores ($P < 0.05$) than LE or Control. There were no differences between LE and Controls in left leg scores. Degree of unsoundness of the legs of Control boars increased from the sixth to tenth week but there were no time differences in LE or HE groups, thus indicating that exercise decreased the degree and delayed the onset of leg weakness. Eleven of the twelve boars had a small inside or outside toe. Size of toes did not have any apparent influence on leg appearance.

Cartilage and bone appraisal. Table 4 presents the lesion scores for joint cartilage evaluation. When all appraisal sites were combined, there were no significant differences in mean lesion scores. For all treatments, there were no significant differences between the degree of lesions on left and right legs with sites combined. Similarly, there were no significant differences between front and back legs.

When appraisal sites were considered (Table 5), ignoring treatment, the most severe lesions were found on the distal humerus and proximal radius - ulna. The scapula, proximal humerus, distal radius - ulna, acetabulum, proximal femur, distal femur, and distal tibia had less severe lesions than the distal humerus and proximal radius - ulna. The proximal tibia had the least severe lesions of any of the sites examined and was seldom affected.

There were no significant differences between treatments in right humerus moisture, fat, calcium, phosphorus, or calcium to phosphorus ratio (Table 6), thus indicating that exercise did not have any apparent influence on bone mineralization.

Blood serum analyses (Tables 7 and 8). Differences between treatments existed for only three of the thirteen blood serum constituents measured. Blood serum cholesterol increased ($P < 0.05$) from 125 mg/100 ml for Control to 150 and 152 mg/100 ml for LE and HE respectively. Serum albumin was lower ($P < 0.05$) for LE than Control. β - globulin was

TABLE 4

MEAN LESION SCORES FOR APPRAISAL OF ARTICULAR CARTILAGE OF BOARS IN EXERCISE EXPERIMENT (WITH SITES COMBINED)

	Lesion Score				
	Sites and Legs Combined	Left Legs vs. Right Legs		Front Legs vs. Back Legs	
		All Sites	All Sites	All Sites	All Sites
Control	0.40a	0.43bc	0.38abc	0.58ab	0.23ab
LE	0.14a	0.10a	0.18ab	0.20ab	0.08a
HE	0.46a	0.55c	0.38abc	0.50b	0.43ab
SE	0.10	0.09		0.14	

TABLE 5

MEAN SCORES FOR APPRAISAL OF ARTICULAR CARTILAGE

CONSIDERING SITES ON LEGS

Site	Scapula	Proximal Humerus	Distal Humerus	Proximal Radius Ulna	Distal Radius Ulna
Score	0.13ab	0.33ab	0.88c	0.58bc	0.21ab
Site	Acetabulum	Proximal Femur	Distal Femur	Proximal Tibia	Distal Tibia
Score	0.26ab	0.33ab	0.32ab	0.04a	0.26ab

TABLE 6

CHEMICAL ANALYSIS OF RIGHT HUMERUS SHAFT AS INFLUENCED BY TREADMILL EXERCISE

	Moisture %	Fat % Dry Basis	Calcium (%) Dry, Fat-free Basis	Phosphorus (%) Dry, Fat-free Basis	Ca / P
Control	18.7	22.4	27.4	10.6	2.61
LE	17.4	20.7	26.9	9.7	2.81
HE	19.9	20.1	27.6	9.9	2.81
SE	0.84	2.61	0.46	0.43	0.14

TABLE 7

BLOOD SERUM CALCIUM, INORGANIC P, ALK. P, GLUCOSE, CHOLESTEROL, LDH AND SGOT FOR BOARS IN EXERCISE EXPERIMENT

	Calcium (mg/100 ml)	Inorg. P (mg/100 ml)	Alk. P (mU/ml)	Glucose (mg/100 ml)	Cholesterol (mg/100 ml)	LDH (mU/ml)	SGOT (mU/ml)
Treatment							
Control	11.1	9.1	186	127	125a	488	78.5
LE	10.9	9.2	212	113	150b	427	68.3
HE	10.9	8.9	200	109	152b	430	73.8
SE*	0.25	0.22	16.8	10.9	6.98	45.1	10.07
Time							
Week 2	11.1	9.3b	238c	126b	143	376	58.6
Week 6	10.8	9.1ab	197b	120b	139	450	75.0
Week 10	10.9	8.7a	163a	104a	146	519	86.9
SE	0.11	0.17	7.96	4.42	3.49	44.1	16.0

*SE - standard error of means
Convert Alk. P to King-Armstrong Units/100 ml by dividing above values by 7.1.
Convert SGOT to Henry Units by dividing above values by 0.483.

TABLE 8

BLOOD SERUM BUN, TOTAL PROTEIN AND ELECTROPHORETIC COMPONENTS FOR SERUM PROTEIN OF BOARS IN EXERCISE EXPERIMENT

	BUN mg/100 ml	Total Protein (g/100 ml)	Albumin (g/100 ml)	Globulins (g/ 100 ml) α	β	γ
Treatment						
Control	12.0	6.5	3.22b	1.06	1.09a	1.10
LE	13.4	6.5	2.80a	1.11	1.33b	1.25
HE	12.1	6.4	2.98ab	1.19	1.18ab	1.08
SE	0.29	0.21	0.10	0.05	0.05	0.05
Time						
Week 2	12.4	6.0a	2.82a	1.08	1.07a	1.03a
Week 6	13.3	6.6b	3.16b	1.08	1.19b	1.22b
Week 10	11.8	6.8b	3.02ab	1.20	1.34c	1.19b
SE	0.21	0.09	0.07	0.05	0.04	0.05

higher ($P < 0.05$) for LE than Control. For both, HE was intermediate between Control and LE. Examination of the data revealed no significant differences in the albumin to globulin ratio between the treatments, thus indicating that immunological mechanisms were not influencing greatly, the level of protein fractions.

There were changes in several of the blood serum measurements between 2,6 and 10 weeks. Concentrations of inorganic phosphorus, alkaline phosphatase and glucose decreased between the second and the tenth week of the experiment. Concentrations of total protein, albumin, β-globulin and γ-globulin increased between the second and tenth week. The observed values of inorganic phosphorus follow the changes with age reported by Ullrey et al. (1967). Similarly, the changes in total protein, albumin, β-globulin and γ-globulin compare quite well with changes with age reported by Miller et al. (1961). Therefore, it may be concluded that observed changes in the blood constituents between the second and tenth week were normal developmental changes occurring as the animals increased in age.

Correlation coefficients for the relationship between lesion score of the distal humerus and each blood constituent were very low (Appendix Table 1). They indicated no relationship between the incidence and severity of cartilage lesions and the blood parameters evaluated.

The results of this experiment indicate that exercise will prevent abnormalities such as bow legs, flexion of the carpus, and sickle leg from impairing the mobility of boars. This is in agreement with observations of Grondalen (1974f). He speculated that muscular strength increases with exercise, however no evidence has been presented to confirm such a speculation. The degree of joint lesions in this experiment was not influenced by exercise. This is also in agreement with Grondalen (1974f).

PART II

INCIDENCE OF ARTHROSIS IN GROWING MALE PIGS SLAUGHTERED AT SUCCESSIVE STAGES OF GROWTH

Introduction and Objectives

Joint and bone lesions have been described in market weight pigs on the basis of postmortem examinations. However, very few investigations have examined leg joints of very young pigs to determine whether articular cartilage lesions occurred in growing pigs at earlier stages of growth (Grondalen, 1974a).

The objectives of this experiment were:

(1) To establish age and weight when cartilage lesions developed in young, growing male pigs.

(2) To examine the effect of soft or hard floors on the incidence and severity of cartilage lesions in pigs.

(3) To examine any relationships that may exist between (a) growth rate, (b) blood serum chemical constituents, (c) muscularity, (d) bone mineralization, and the incidence and severity of cartilage lesions.

Materials and Methods

Ninety-six boars, four from each of twenty-four litters, were purchased from two swine breeders.[4] The animals were selected at random at three days of age and allotted to the experiment. Eight boars selected from two litters farrowed at approximately the same time constituted one replication. Serial slaughter of the boars in each of twelve replications was planned according to the outline in Table 9. Litters and pigs within litters were allotted to slaughter ages (or weights) randomly by computer. The pigs assigned to slaughter at three days of age were killed by administration of a lethal dose of Nembutal. The remaining pigs were weaned at an average age of 27.5 days of age (range 21-36 days). The pigs were held at the two farms for at least one week after weaning and then they were all moved to The University of Alberta Edmonton Research Station (ERS) at the same time. Pre-weaning management of the pigs followed standard practices for Alberta as outlined by Aherne et al. (1974) although there were some minor variations between the two farms because of different housing

[4]Wallace Orr, Box 6, Fort MacLeod, Alberta and Wayne Smith, R.R.1 Hillspring, Alberta.

TABLE 9

ALLOTMENT OF PIGS IN EACH REPLICATION TO TIME OR WEIGHT OF SLAUGHTER

Slaughter Age (or Weight)	Litter 1 Number of Pigs	Litter 2 Number of Pigs
3 days	1	
Weaning[+]		1
0 ----------	----------	----------
20 kg	1	
40 kg		1
60 kg	1	
80 kg		1
100 kg	1	
120 kg		1
0		

[+]Weaning is the name used to denote the group of pigs slaughtered after weaning and movement to ERS.

[0]Broken line denotes start of floor treatments.

and management techniques preferred by the two farm operators. Two ml injectable iron[5] was administered to pigs at both farms within three days of birth. At both farms sows were fed a nursing sow ration at levels to meet NAS-NRC (1973) requirements. Nursing piglets were allowed access to commercially prepared creep diets at one week of age. Pigs were weaned into concrete floored pens at one farm and into raised steel pens with expanded metal floors at the other farm. Weaned piglets were given commercially prepared pre-starter diets ad libitum. Water was also available ad libitum.

The boars allotted to be slaughtered shortly after weaning were killed five days after arriving at ERS. The remaining boars were then penned in groups of six, three boars from each of two litters, per pen. There were some pre-weaning deaths of pigs assigned to the experiment so littermate boars were assigned wherever possible to the missing cell at allotment to pens.

Six replications were housed in a barn with concrete floor and a minimum of wood shaving bedding and the remaining six replications were housed in an earth floor barn with deep cereal straw bedding. Each replication was housed in pens measuring 3.13 m x 1.41 m. Table 10 shows the number of pigs per pen and the floor area per pig throughout the

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[5]Imposil 200: Iron dextran complex. Fisons (Canada) Limited. 26 Prince Andrew Place, Don Mills, Ontario. 2 ml dose contains 200 mg iron.

TABLE 10

NUMBER OF PIGS PER PEN AND FLOOR AREA PER PIG THROUGHOUT THE DURATION OF THE SERIAL SLAUGHTER EXPERIMENT

Weight range (kg)	Number of Pigs per Pen	Floor Area Per Pig (m^2)
Start - 20	6	0.74
21 - 40	5	0.88
41 - 60	4	1.10
61 - 80	3	1.47
81 - 100	2	2.21
101 - 120	1	4.41

duration of the experiment.

Temperatures of the barns was maintained at 22 C until the pigs allotted to the 20 kg group were slaughtered. The temperature from that time until the end of the experiment was maintained at 16 - 20 C.

Diets and pig weights. The pigs were fed a starter diet ad libitum (Table 11) from the time they arrived at ERS until allottment to their pens and then until the first pig was withdrawn from each pen for slaughter at 20 kg. At that time the remaining five pigs were given a pelletted grower diet ad libitum (Table 12). The same grower diet was fed throughout the experiment and was mixed as required. Water was available ad libitum from automatic quench drinkers. Feed consumption for each replication was recorded when an animal was withdrawn for slaughter in order to obtain a measure of feed consumption and feed efficiency for the successive growth phases.

Pigs were weighed weekly and also when pigs were withdrawn from replications for slaughter if the two days did not coincide.

Blood serum analyses. Blood serum samples were collected from each pig just prior to slaughter. Collection method, treatment after collection and blood serum chemical analyses were as described in Part I of this thesis.

TABLE 11

FORMULATION AND COMPOSITION (AS FED BASIS) OF STARTER DIET IN SERIAL SLAUGHTER EXPERIMENT

Ingredients (%)	
Barley (ground)	21.2
Wheat (ground)	41.2
Oats (ground)	2.5
Soybean meal (48.5% protein)	20.0
Meat meal (55% protein)	2.0
Herring meal (70% protein)	3.0
Rapeseed meal (36% protein)	2.5
Stabilized tallow	4.0
Limestone	0.7
Dicalcium phosphate	1.0
Salt (iodized)	0.4
Trace mineral-vitamin premix[+]	1.5
Composition (by analysis)	
Crude protein (%)	20.2
Gross energy (kcal/kg)	3999
Calcium (%)	0.88
Phosphorus (%)	0.76

[+]The premix supplied the following per 100 kg diet: 0.28 g cobalt; 2.46 g copper; 29.4 g iron; 7.62 g manganese; 8.85 g zinc, 440,000 IU vitamin A; 55,000 IU vitamin D; 1100 IU vitamin E; 1110 mg riboflavin; 2220 mg calcium pantothenate; 5050 mg niacin; 5570 mg choline; 165 mg folic acid; 1.98 mg vitamin B_{12}. It also supplied 500 mg Terramycin -10.

TABLE 12

FORMULATION AND COMPOSITION (AS FED BASIS) OF GROWER DIET IN SERIAL SLAUGHTER EXPERIMENT

Ingredients (%)	
Barley (ground)	52.0
Wheat (ground)	26.5
Soybean meal (48.5% protein)	12.5
Herring meal (70% protein)	2.5
Stabilized tallow	2.5
Limestone	0.5
Dicalcium phosphate	2.0
Salt (iodized)	0.5
Trace mineral-vitamin premix[+]	1.0
Composition (by analysis)	
Crude protein (%)	15.9
Gross energy (kcal/kg)	3853
Calcium (%)	0.93
Phosphorus (%)	0.91

[+]The premix supplied the following per 100 kg diet: 0.11 g cobalt; 0.98 g copper; 11.76 g iron; 3.05 g manganese; 8.85 g zinc; 440,000 IU vitamin A; 55,000 IU vitamin D; 550 IU vitamin E; 444 mg riboflavin; 888 mg calcium pantothenate; 2020 mg niacin; 2228 mg choline chloride; 66 mg folic acid; 990 mg vitamin B_{12}. It also supplied 50 g of Aurofac-10.

Cartilage, bone appraisal and carcass analyses. The boars were killed by mechanical stunning when they reached the killing weight they had been allotted to at the beginning of the experiment. Immediately following slaughter, the two right legs were dissected out and frozen on dry ice (-42.8 C) to preserve cartilage for a chemical study of cartilage not part of this thesis. The frozen right legs were thawed sufficiently to open the joints and the cartilage of major joints was examined and evaluated as described in Part I of this thesis.

The left side of each carcass was taken to the Department of Animal Science Meats Laboratory for separation into bone and soft tissue (containing lean and fat), after it was divided into front and hind parts and the skin was removed. Soft tissue and bone weights were recorded. The soft tissue was ground twice through a meat grinder, mixed and a representative sample (100 g) was selected by combining several small grab samples. The sample of tissue was analyzed for dry matter, protein, fat and ash (A.O.A.C. 1970). Cartilage of major limb joints was examined and evaluated as described above except that dissected bones had been stored in a frozen condition.

Methods of statistical analyses. Three crossbred pigs from the 120 kg weight allotment group died before weaning and there were no pigs to replace them. They accounted for three missing cells in the analysis of data.

One pig in the 100 kg group became crippled at 55 kg and was slaughtered at that weight. Data from that pig was excluded from the analysis. Three pigs in the earth floor group were killed at light weights because the barn temperature could not be maintained at 16 C when they were the only pigs remaining. One pig in the concrete floor group was killed at a light weight because it grew slowly. Analyses of variance were computed to determine significant differences. The sources of variation for analyzing the data for feed and growth on a pen basis were weight growth phases (N = 6), breed (N = 2), floor (N = 2), and pens per breed (N = 3). Four observations were missing in the sixth weight and an analysis of covariance program was used to estimate those missing values. These values were then used in the analysis of variance. The sources of variation for analyzing the growth, bone chemical analysis, blood serum constituents, carcass dissection and tissue proximate analysis were as follows: breed (N = 2), floor (N = 2), units (litters within replicates) (N = 2), slaughter weights (within units) (N = 4) and litters (within units, breed and floor) (N = 3). Eight cells were missing from this data and they were estimated by analyses of covariance. These values were then used in the analysis of variance. To calculate error mean square, 1 degree of freedom was subtracted for each missing value estimated by analysis of covariance

procedure.

The sources of variation for analysis of the cartilage lesion data were the same as the growth and bone chemical analysis group except that right and left legs (N = 2) were also considered. Analysis of covariance program was used to estimate missing values on a total pig lesion score basis, considering all sites and legs. This estimated value was then divided up within the missing cell according to the weighting of lesion scores of pigs within the weight group from which the cell was missing. These values were then used in the analysis of variance. Degrees of freedom were subtracted again in the calculation of error mean score.

Multiple comparison of means, where appropriate, were made using Duncan's multiple range test (Steel and Torrie, 1960) and means not significantly different ($P < 0.05$) bear the same letter or no letter.

Correlation coefficients were calculated to determine the relationship in lesion scores between sites and also to examine the relationship between lesion scores and blood serum constituents.

Results and Discussion

There were no obvious disease problems with the pigs during the experiment. Turbinate and lung samples of several pigs killed shortly after weaning were submitted to the Veterinary Services Division, Alberta Agriculture to obtain an evaluation of respiratory disease status. The histopathological report indicated a mild nasal and lung infection, although no distinct atrophy of turbinates was noted.

Table 13 summarizes the performance, feed consumption and efficiency of feed conversion on a pen basis for the six growth phases from the start of test to 120 kg. There were no floor or breed differences in average daily gain (ADG), average daily feed (ADF), or efficiency of feed conversion (EFC). There were also no significant differences in floor X growth period or breed X growth period interactions so those means were not compared by Duncan's test. As one would expect, there were highly significant ($P < 0.001$) differences in the growth period means for ADG. The lowest ADG of 0.46 kg/day occurred for the first period and the greatest ADG of 0.87 kg/day was during the last growth phase. Periods 2 to 5 were intermediate in growth rate.

ADF increased from 0.83 kg/day in the first period to 3.38 kg/day in the fifth period and then decreased during the last period to 2.95 kg/day.

TABLE 13

PERFORMANCE OF PIGS ON A PEN BASIS FOR THE SIX GROWTH PHASES OF SERIAL SLAUGHTER

Period	Start to 20 kg	20-40 kg	40-60 kg	60-80 kg	80-100 kg	100-120 kg	Standard Error of Mean
ADG (kg/day)							
Breed							
Yorkshire	0.46	0.73	0.81	0.84	0.86	0.81	
Crossbred	0.46	0.71	0.80	0.83	0.80	0.94	
Treatment							
Concrete Floor	0.45	0.72	0.91	0.82	0.84	0.78	
Earth Floor	0.47	0.72	0.70	0.84	0.83	0.97	
Overall Mean	0.46a	0.72b	0.80bc	0.83bc	0.83bc	0.87c	0.05
ADF (kg/day)							
Breed							
Yorkshire	0.80	1.70	2.52	2.91	3.33	3.09	
Crossbred	0.87	1.81	2.52	3.23	3.44	2.81	

TABLE 13 (Continued)

Period	Start to 20 kg	20-40 kg	40-60 kg	60-80 kg	80-100 kg	100-120 kg	Standard Error of Mean
Treatment							
Concrete Floor	0.82	1.76	2.58	2.86	3.36	3.19	
Earth Floor	0.84	1.75	2.46	3.27	3.40	2.71	
Overall Mean	0.83a	1.75b	2.52c	3.07d	3.38d	2.95cd	0.16
EFC (kg feed/kg gain)							
Breed							
Yorkshire	1.76	2.34	3.47	3.54	3.94	4.14	
Crossbred	1.89	2.55	3.15	3.94	4.48	3.45	
Treatment							
Concrete Floor	1.86	2.46	2.84	3.55	4.14	4.15	
Earth Floor	1.79	2.43	3.78	3.93	4.28	3.44	
Overall Mean	1.83a	2.44a	3.31b	3.74bc	4.21c	3.80bc	0.26

TABLE 14a

AGE OF BOARS (DAYS) AT THE EIGHT SLAUGHTER TIMES

	Age or Weight at Slaughter								
	3 days	Wean	20	40	60	80	100	120	SE
Breed									
Yorkshire	3a	39b	75c	95d	124e	141f	163g	179h	2.95
Crossbred	3a	46b	69c	96d	123e	145f	168g	183h	
Treatment									
Concrete floor	3a	43b	71c	96d	122e	143f	165g	182h	2.95
Earth floor	3a	43b	74c	95d	126e	144f	167g	181h	
Overall Mean	3a	43b	72c	96d	124e	143f	166g	181h	2.09

TABLE 14b

DAYS ON TEST AND AVERAGE DAILY GAIN (ADG) OF BOARS

FROM START OF TEST UNTIL SLAUGHTER

	Weight at Slaughter (kg)						
	20	40	60	80	100	120	SE
Days on Test							
Breed							
Yorkshire	33a	55b	83c	102d	122e	139f	3.03
Crossbred	27a	52b	81c	101d	126e	138f	
Treatment							
Concrete floor	28a	56b	80c	103d	123e	139f	3.03
Earth floor	32a	51b	84c	100d	125e	138f	
Overall Mean	30a	53b	82c	101d	124e	138f	2.14

TABLE 14b (Continued)

	Weight at Slaughter (kg)						
	20	40	60	80	100	120	SE
ADG (kg)							
Breed							
Yorkshire	0.49a	0.60b	0.65b	0.71bc	0.73bc	0.81d	0.08
Crossbred	0.44a	0.65b	0.74bc	0.60b	0.72bc	0.76d	
Treatment							
Concrete floor	0.50a	0.58b	0.66b	0.71c	0.73c	0.81d	0.08
Earth floor	0.43a	0.61b	0.64b	0.72c	0.74c	0.77d	
Overall Mean	0.46a	0.60b	0.65b	0.71c	0.73cd	0.79d	0.02

EFC of 1.83 and 2.44 kg feed/kg gain were not different ($P < 0.05$) for the first two growth periods. Pigs during periods 3, 4 and 6 were intermediate in EFC with 3.31, 3.74 and 3.80 kg feed/kg gain respectively. EFC during period 5 was somewhat higher than periods 1, 2 and 3 but did not differ significantly ($P < 0.05$) from periods 4 and 6. During periods 2, 3 and 4 there was considerable wastage of feed because of competition among pigs at the self feeders, causing spillage. The wastage was minimized when the number of pigs in the pens was reduced.

There were no differences ($P < 0.05$) (Table 14a) between breed or floor treatment in the age of pigs at slaughter. Growth of the pigs was good with an average age at 120 kg of 181 days. Pigs slaughtered at 80 and 100 kg were 143 and 166 days of age which may be slower growth than average for boars. Days on test are shown in Table 14b. Again, there were no treatment or breed differences. Cumulative ADG of the boars from time of allotment to treatments until slaughter at the six weight groups are shown in Table 14b. There were no treatment or breed differences at any of the slaughter weights. ADG increased from 0.46 kg/day for the pigs slaughtered at 20 kg to a high of 0.79 kg/day for pigs slaughtered at 120 kg. Pigs killed at 40, 60, 80 and 100 kg had, as one might expect, increasing ADG with increasing weight of pigs.

Blood serum analyses. Blood serum measurements reported are based on single analysis of blood samples. Evaluation of the technical performance of the SMA 12/60 (Finley et al. 1969) shows an excellent repeatability with coefficient of variations ranging from a low 0.9 for phosphorus and blood urea nitrogen to a high of 7.0 for SGOT. Okai (1975) obtained good repeatability between samples for all values except those for enzymes, which appeared to be affected by hemolysis of the blood samples.

Means values reported herein (Tables 15 and 16) are overall means at each slaughter time or weight. There were no significant breed or treatment differences ($P < 0.05$) for blood serum constituents when each weight group was considered. There were changes in nearly all serum constituents with increasing age of the pigs.

Total protein decreased slightly from 5.59 g/100 ml at 3 days to 5.0 g/100 ml at 43 days (shortly after weaning) and then increased to 7.0 g/100 ml at 181 days of age. During the same time, albumin increased from 1.25 to 3.29 g/100 ml, most of the increase occurring by the time the pigs were 43 days old. α-globulin concentrations were the same throughout the experiment while β-globulin decreased ($P < 0.05$) between 3 days and 43 days from 1.18 to 0.99 g/100 ml respectively and then gradually increased to a level of 1.35 g/100 ml at 120 kg. γ-globulin was high (1.86 g/100 ml) at 3 days of age and then decreased ($P < 0.05$)

TABLE 15

TOTAL PROTEIN (TPROT), ALBUMIN (ALB), α-GLOBULIN (α-GLOB), β-GLOBULIN (β-GLOB), γ-GLOBULIN (γ-GLOB) AND BLOOD UREA NITROGEN (BUN) IN SERUM OF BOARS AT DIFFERENT SLAUGHTER TIMES AND WEIGHTS

	3 days	wean	20	40	60	80	100	120	SE
T.Prot (g/100ml)	5.5ab	5.0a	5.9b	6.7cd	6.5c	6.9cd	7.1d	7.0cd	0.17
Alb (g/100ml)	1.25a	2.43b	2.83c	3.09cde	3.04cd	3.18de	3.38e	3.29de	0.10
α-Glob (g/100ml)	1.19a	1.08a	1.11a	1.11a	1.11a	1.04a	1.11a	1.07a	0.04
β-GLOB (g/100ml)	1.18ab	0.99a	1.13a	1.40c	1.38bc	1.43c	1.38c	1.35bc	0.06
γ-GLOB (g/100ml)	1.86d	0.55a	0.83ab	1.11bc	1.05bc	1.16bc	1.26c	1.28c	0.11
Alb/TPROT (%)	23.0a	48.6b	48.1b	46.0b	46.6b	47.6b	47.8b	47.0b	1.33
α-GLOB/TPROT (%)	22.2c	21.3bc	18.7ab	16.4a	17.0a	15.2a	15.4a	15.3a	1.16
β-GLOB/TPROT (%)	21.6a	19.6a	19.2a	20.8a	20.8a	20.7a	19.3a	19.3a	0.94
γ-GLOB/TPROT (%)	32.9c	10.8a	14.2ab	16.5b	16.1b	17.2b	16.7b	18.4b	1.44
BUN (mg/100ml)	10.1a	19.4d	13.9bc	14.7bc	11.4ab	16.3cd	14.8bc	12.3ab	1.20

TABLE 16

CALCIUM, INORGANIC PHOSPHORUS (INORG P), ALKALINE PHOSPHATASE (ALK P), GLUCOSE, CHOLESTEROL, LACTATE DEHYDROGENASE (LDH), SERUM GLUTAMIC OXALOACETIC TRANSAMINASE (SGOT) IN BLOOD SERUM OF BOARS AT DIFFERENT SLAUGHTER TIMES

	3 days	Wean	20	40	60	80	100	120	SE
Calcium (mg/100ml)	11.1bc	9.6a	10.8b	11.4c	10.8b	11.0bc	11.0bc	11.2bc	0.17
Inorg P (mg/100ml)	7.8a	8.1ab	10.2d	10.4d	9.0c	8.7bc	8.2ab	7.8a	0.27
Alk P (mU/ml)	888c	296b	254ab	216ab	171ab	170ab	160ab	139a	42.4
Glucose (mg/100ml)	143d	99a	145d	140d	120bc	121c	105abc	102ab	6.24
LDH (mU/ml)	394a	497bc	565c	478b	451ab	502bc	384a	444ab	25.9
SGOT (mU/ml)	83b	72ab	116c	88bc	66ab	80ab	49a	79ab	10.3
Cholesterol (mg/ 100 ml)	131c	103a	106a	113ab	103a	111ab	125bc	110ab	5.31

to 0.55 and 0.83 g/100 ml at 43 days and 20 kg respectively. γ-globulin then increased gradually between the last 5 periods.

The observed changes of protein fractions are in agreement with Miller et al. (1961). The principal changes occurred in the γ-globulin and albumin fractions. γ-globulin was high in the 3 day pigs because of absorption from colostrum of the dams of the piglets. Miller et al. (1961) indicated that there was little or no γ-globulin production by the baby pig in the first three weeks of life and this could account for the low level observed at 43 days of age in this experiment. Miller et al. (1961) reported that the production of serum albumin begins very rapidly after birth and reaches a high level shortly after three weeks of age without substantial change from then up to six months of age. Large increases in γ-globulin after three weeks of age could be considered to be an antibody or immunological response. Such response was not noted in this experiment as measured by γ-globulin/total protein (%) and would indicate no major infectious agents being active.

Blood urea nitrogen (BUN) increased from 10.1 mg/100 ml at 3 days of age to 19.4 mg/100 ml at 43 days and then decreased to 13.9 mg/100 ml at 20 kg. The BUN levels for 20 kg and subsequent slaughter weights did not form a consistent pattern and it is difficult to interpret the

significance of the measurements in relation to this investigation.

Serum calcium levels decreased from 11.1 mg/100 ml at 3 days of age to 9.6 mg/100 ml at 43 days of age. Calcium then increased in the serum to a relatively constant level of 10.8 to 11.2 mg/100 ml of serum. Inorganic phosphorus increased from 7.8 mg/100 ml at 3 days to 10.2 mg/100 ml at 20 kg, remained at that level (10.4 mg/100 ml) at 40 kg and then gradually decreased to 7.8 mg/100 ml. These changes agree very well with Ullrey et al. (1967). Thurley (1971) reported that the calcium, phosphorus product is a relatively good indicator of the rachetic or non-rachetic status of the pig and that the product of the two measurements should be greater than 40. In this investigation, at all weights, the calcium X phosphorus measure was higher than 40. An examination of data of individual pigs revealed no values approaching the low level of 40. This would indicate then, that the nutritional calcium and phosphorus status of the pigs was normal.

Guyton (1966) indicated that alkaline phosphatase is secreted by osteoblasts when bone deposition occurs; and that this hormone diffuses into the blood such that osteoblast or osteoclast activity can be estimated by the relative circulatory concentration. The relatively high level of alkaline phosphatase of 888 mU/ml at 3 days of age and a continual decrease to 139 mU/ml at 120 kg would indicate

a decreased osteoblastic activity and decreased bone growth. It is pertinent to point out the great deal of variability in the measurements of alkaline phosphatase as indicated by the standard error of the means.

Importance of glucose, cholesterol, LDH and SGOT are difficult to interpret in relation to this investigation but appear to be in the normal ranges reported by Kaneko and Cornelius (1970) and converted to the units reported in Table 16.

Appraisal of joint cartilage. The cartilage lesions that were observed most often are illustrated in Plates 1 to 6. Plate 1 presents the proximal humerus joint of the front leg and shows a roughening of cartilage and depression grooves that may result from abnormal high pressure in the small areas concerned. The most common cartilage lesion of the distal humerus (Plate 2) appears as an irregularity and splitting of cartilage with apparent collapse of the subchondral bone. Severe lesions of this nature were characterized by lifting of the cartilage and, in some cases, removal of the cartilage from the affected area. The underlying bone appeared spongy and soft in nature.

Plates 3 and 4 show typical lesions of the proximal femur. They appeared as a flattening of the top (Plate 3) of the femoral head and grooving on both sides (Plates 3 and 4) near the bottom of the femoral head. Again the grooves may result from abnormal pressure in those areas.

Plate 1. Proximal humerus of a pig. The cartilage surface is rough and shows "wear grooves".

Plate 2. Split, separated cartilage with collapsed subchondral bone tissue in the medial condyle of the humerus of a pig.

Plate 3. Femoral head of a pig showing flattened appearance and evidence of collapse of subchondral bone.

Plate 4. Femoral head of a pig showing "wear groove" on right side of bone.

TABLE 17a

PERCENTAGE INCIDENCE OF ARTHROSIS IN BOARS AT THE EIGHT SLAUGHTER WEIGHTS

Site	P.HUM	D.HUM	P.RAD	D.RAD	P.FEM	D.FEM	P.TIBIA	D.TIBIA
3 days	0a	0a	0a	0a	0a	0a	0a	0a
Wean	4.2a	25.0b	8.3b	0a	4.16a	8.3b	0a	0a
20	12.5bc	4.16a	8.3b	4.16b	16.7b	0a	0a	4.16b
40	12.5bc	20.8b	8.3b	0a	58.3c	0a	0a	4.16b
60	16.7c	50.0d	16.7c	4.16b	25.0b	0a	0a	4.16b
80	16.7c	41.7c	20.8c	8.3c	75.0d	8.3b	4.16b	25c
100	10.0b	50.0d	15.0d	15.0d	75.0d	0a	0a	5b
120	61.0d	83.0e	44.4e	27.8e	78.0d	44.4c	33.3c	0a
SE	1.57	2.51	1.23	0.89	3.06	1.40	1.06	0.75

There were several observations of thin, red and occasionally rough cartilage on the medial condyles of the humerus (Plate 5). The cartilage appeared quite transparent and the red appearance probably resulted fom the color of the underlying bone.

Plate 6 presents the typical lesion observed in the cartilage of the proximal radius-ulna and consisted of an erosion and disappearance of the cartilage in an area of the ulnar notch. It was quite often accompanied by the splitting of cartilage in the adjacent medial condyle of the humerus as shown in Plate 6.

The incidence of cartilage lesions in the leg joints examined, ignoring breeds and treatments, are presented in Table 17a. Table 17b presents information of the same nature comparing the two breeds and Table 17c compares the incidence of lesions of pigs on the concrete floor compared with the earth floor. Figures 1 and 2 present the percent incidence of arthrosis in the D. HUM and P. FEM respectively.

The incidence of arthrotic lesions generally increased with increasing weights of the boars. Figure 1 suggests that incidence of lesions in the distal humerus increases greatly between the 40 and 60 kg weights and again at 120 kg. Figure 2 shows that there was a high incidence of lesions of the P. FEM of the boars in this experiment, a somewhat lower incidence in the boars at 60 kg and a high incidence (75-78%) in the last 3 groups of boars.

TABLE 17b

PERCENTAGE INCIDENCE, BY BREED, OF ARTHROSIS IN P.HUM, D.HUM, P.RAD AND P.FEM AT SEVEN* SLAUGHTER WEIGHTS

	Weight or Age							
	Wean	20	40	60	80	100	120	SE
P.HUM								
Yorkshire	0a	8.3b	16.7d	16.7d	33e	12.5c	67g	1.18
Crossbred	8.3b	16.7d	8.3b	16.7d	0a	8.3b	50f	
D.HUM								
Yorkshire	25c	0a	50e	58.3f	41.7d	62.5fg	92.5h	1.63
Crossbred	25c	8.3b	0a	41.7d	41.7d	41.7d	67g	
P.RAD								
Yorkshire	16.7c	8.3b	8.3b	8.3b	33e	0a	41.7f	1.39
Crossbred	0a	8.3b	8.3b	25d	8.3b	25d	33e	
P.FEM								
Yorkshire	0a	16.7c	67f	41.7d	92.5i	62.5ef	75g	1.68
Crossbred	8.3b	16.7c	41.7d	16.7c	58.3e	83h	83h	

*3day group is not presented in this table because there were no observed lesions.

TABLE 17c

PERCENTAGE INCIDENCE, BY TREATMENT, OF ARTHROSIS IN P.HUM, D.HUM, P.RAD AND P.FEM AT SIX* SLAUGHTER WEIGHTS

	Weight or Age						
	20	40	60	80	100	120	SE
P.HUM							
Concrete floor	16.7b	8.3a	16.7b	16.7b	10.0a	40.0c	1.49
Earth floor	8.3a	16.7b	16.7b	16.7b	10.0a	87.5d	
P.HUM							
Concrete floor	8.3b	33.0d	75.0g	41.7e	50.0f	80.0h	1.62
Earth floor	0a	8.3b	25.0c	41.7e	50.0f	87.5i	
P.RAD							
Concrete floor	16.7c	0a	16.7c	25.0e	10.0b	50.0g	0.95
Earth floor	0a	16.7c	16.7c	16.7c	20.0d	37.5f	
P.FEM							
Concrete floor	25.0c	50.0e	16.7b	50.0e	80.0g	70.0f	1.79
Earth floor	8.3a	67.0f	33.3d	100.0i	70.0f	87.5h	

*3 day & weaning groups are not presented in this table because animals were not allotted to treatments until after weaning.

Plate 5. Distal humerus of a pig. Cartilage appears thin, red and rough.

Plate 6. Elbow joint of a pig. Cartilage on both surfaces is split and separated with collapsed subchondral bone tissue.

FIGURE 1 Percentage Incidence of Arthrosis in the Distal Humerus of Boars at Eight Slaughter Weights

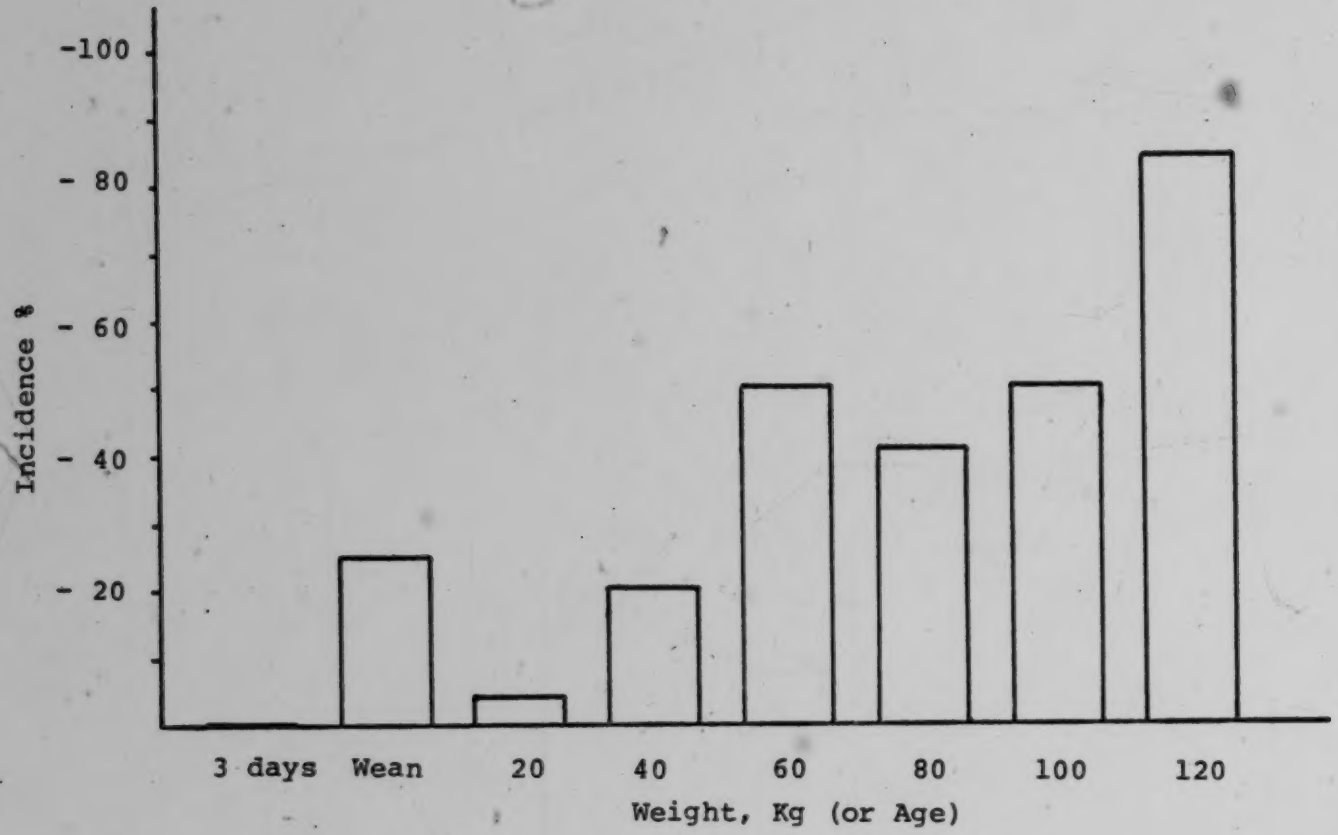
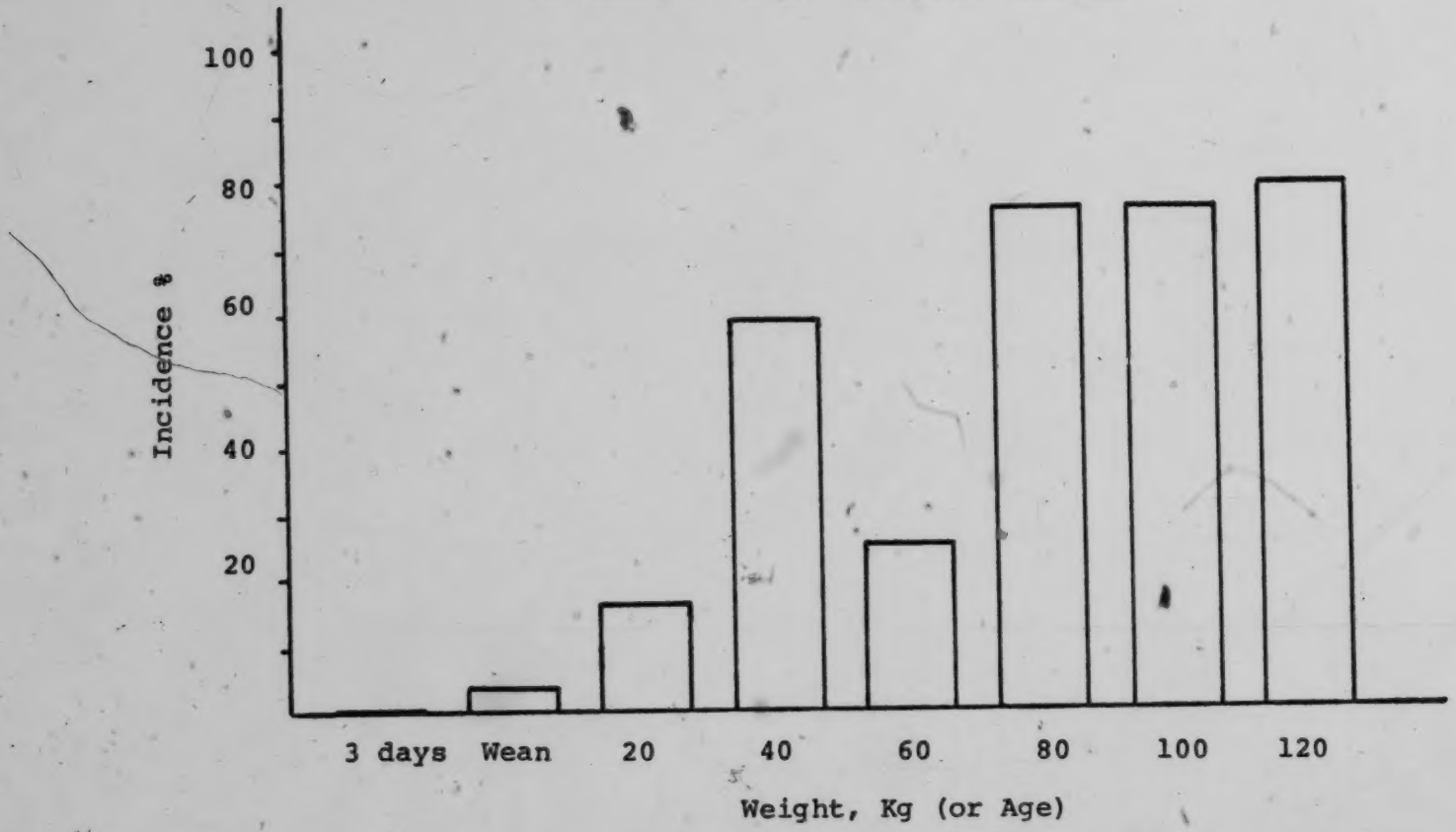


FIGURE 2 Percentage Incidence of Arthrosis in the Proximal Femur of Boars at Eight Slaughter Weights



The joint sites, according to this investigation, may be considered in three groups according to the incidence of lesions; high, medium and low incidence groups. In the high incidence group may be considered the D. HUM and P. FEM with 34.3 and 42.8 percent average incidence for those two joint surfaces respectively. P. HUM and P. RAD may be considered as medium incidence sites with 16.7 and 15.2% average incidence of lesions. The other sites examined may be considered as low incidence lesion areas.

An examination of Table 17b shows no general trend for occurrence in lesions of the D. HUM, P. HUM, P. RAD and P. FEM up to 20 kg. At heavier weights, lesions generally occurred more often in Yorkshire than in Crossbred boars when the P. HUM, D. HUM and P. RAD were considered. Considering the P. FEM there was no definite trend but the Crossbred boars had incidences at 100 and 120 kg of 83% compared with lower ($P < 0.05$) values of 62.5% and 75% for Yorkshire boars of those respective weights.

When comparing incidence of cartilage lesions in the two floor treatments, there were no consistent effects. The average incidence for P. HUM and P. FEM of 13.6 and 36.5% on concrete were lower ($P < 0.05$) than 19.5 and 45.8%, the average incidence for P. HUM and P. FEM on earth floor. There was no difference in the percent incidence between floors in the P. RAD. The average incidence for D. HUM of 36% on concrete floor was higher ($P < 0.05$) than 26.6%

incidence of lesions on earth floor. Considering the treatments at individual weight groups, there was no apparent trend in the incidence of lesions on the two floor treatments.

Table 18a and Table 18b present the severity of cartilage lesions as evaluated by the method described in Part I of this thesis. The various sites can be grouped into similar groups as the above discussion; D HUM and P. FEM being in a most severe incidence group; P. HUM and P. RAD, in an intermediate group and the remaining four sites in a mild group. Severity of lesions generally increased with weight of the pig with the greatest increase occurring from 60 kg upwards in the case of the high incidence group and lesion score increasing later, at 120 kg, in the intermediate group. Most severe mean lesion scores were 1.99 and 1.37 in the D. HUM and P. FEM at 120 kg (Figures 3 and 4).

Table 18b compares the severity of lesions between right and left legs of P. HUM, D. HUM, P. RAD and P. FEM at seven of the slaughter weights. There were only differences ($P < 0.05$) in three of the twenty-eight comparisons and it may be concluded that the severity of lesions did not differ between right and left legs.

Table 19 presents simple correlation coefficients of lesion scores for comparisons between left and right joints at D. HUM, P. RAD and P. FEM. The fifteen comparisons indicated significance ($P < 0.05$) in thirteen of the

TABLE 18a

MEAN CARTILAGE LESION SCORES FOR THE LEG JOINTS EXAMINED

WITH RIGHT AND LEFT LEGS COMBINED

	Joint Site							
	P.HUM	D.HUM	P.RAD	D.RAD	P.FEM	D.FEM	P.TIBIA	D.TIBIA
Wean	0.04a	0.25ab	0.08a	0a	0.04a	0.08a	0a	0a
20	0.13a	0.04a	0.08a	0.04ab	0.17a	0a	0a	0.04a
40	0.13a	0.38ab	0.08a	0a	0.58b	0a	0a	0.04a
60	0.17a	0.63ab	0.16a	0.04ab	0.29ab	0a	0a	0.04a
80	0.17a	0.75bc	0.21a	0.08ab	1.08c	0.08a	0a	0.25b
100	0.10a	1.29c	0.30a	0.15b	1.14c	0a	0.04a	0.05a
120	0.63b	1.99d	0.79b	0.40c	1.37c	0.72b	0.33b	0a
SE	0.07	0.20	0.10	0.04	0.12	0.05	0.03	0.04

TABLE 18b

MEAN CARTILAGE LESION SCORES FOR THE LEG JOINTS EXAMINED

COMPARING RIGHT AND LEFT LEGS

Site	P.HUM		D.HUM		P.RAD		P.FEM	
	Left	Right	Left	Right	Left	Right	Left	Right
Wean	0.08ab	0a	0.08ab	0.42abc	0a	0.17a	0a	0.08a
20	0.08a	0.17ab	0a	0.08ab	0a	0.17a	0.17ab	0.17ab
40	0.17ab	0.08ab	0.42abc	0.33abc	0a	0.17a	0.67bcd	0.50abc
60	0.33b	0a	0.50abcd	0.75bcde	0a	0.33ab	0.50abc	0.08a
80	0.08ab	0.25ab	0.58abcd	0.92de	0.17a	0.25a	1.17def	1.0cde
100	0.20ab	0a	1.39ef	1.18ef	0.10a	0.50ab	1.39ef	0.89cde
120	1.1c	0.15ab	1.76fg	2.23g	0.79b	0.79b	1.62f	1.12de
SE	0.09		0.22		0.15		0.16	

FIGURE 3 Mean Lesion Scores of the Distal Humerus of Boars from Weaning to 120 kg.

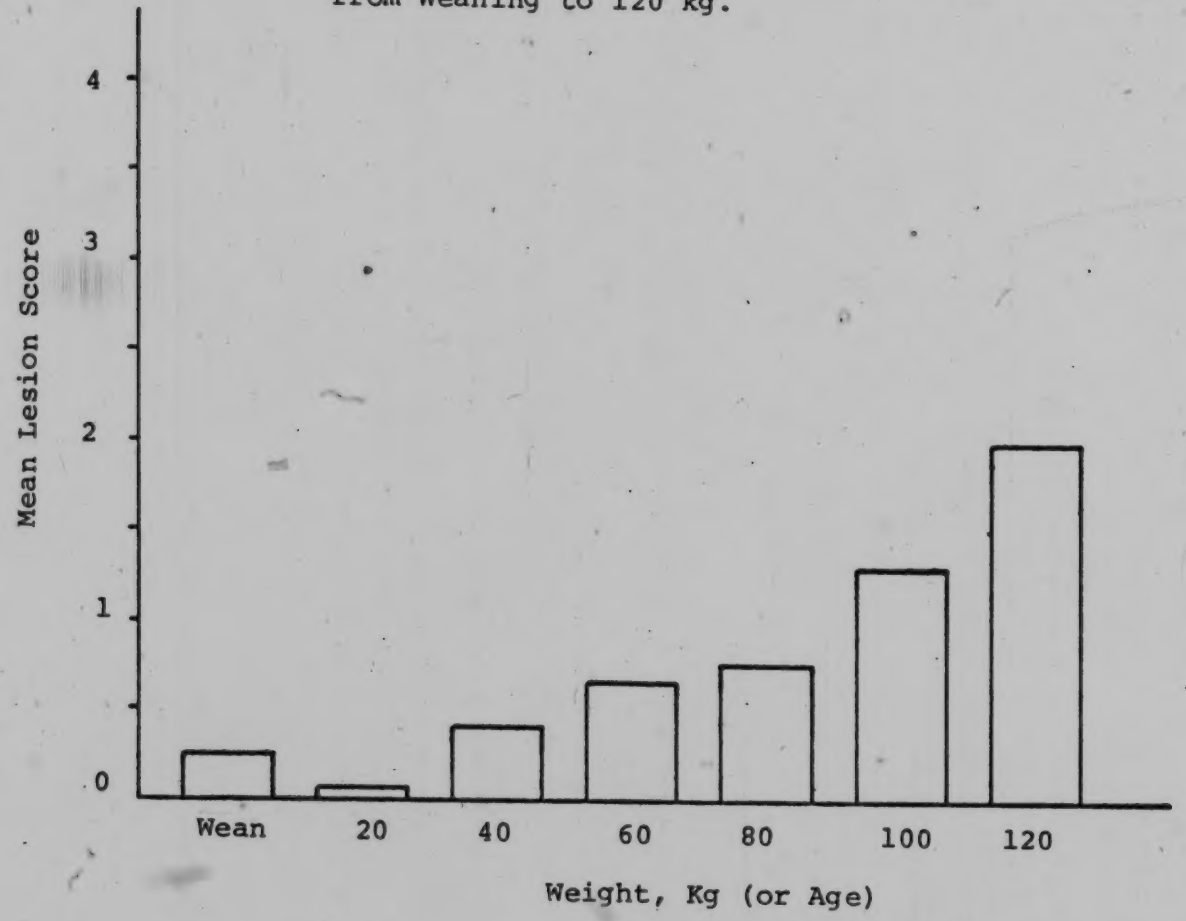


FIGURE 4 Mean Lesion Scores in the Proximal Femur of Boars from Weaning to 120 kg.

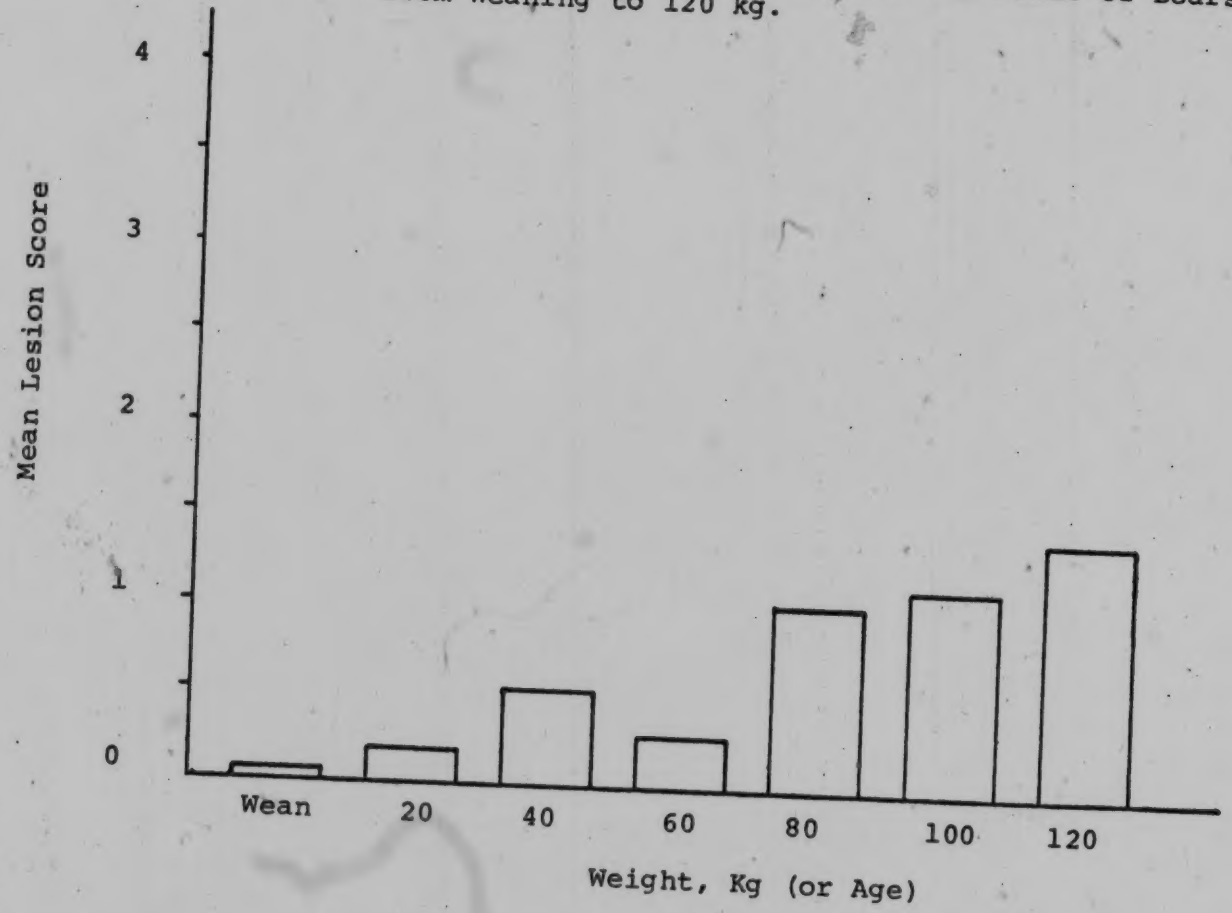


TABLE 19

CORRELATION COEFFICIENTS CALCULATED FOR CARTILAGE LESIONS AT JOINT SITES WITH OTHER JOINT SITES

	R.P.FEM	LP.FEM	RP.RAD	LP.RAD	RD.HUM
LP.FEM	0.52***[1]				
RP.RAD	0.11	0.19*			
LP.RAD	0.50***	0.31**	0.09		
RD.HUM	0.37***	0.49***	0.58***	0.45***	
LD.HUM	0.37***	0.39***	0.23*	0.56***	0.58***

[1] * - indicates significance at ($P < 0.05$), ** - significance at ($P < 0.01$), *** - significance at ($P < 0.001$).

correlations. Of interest, the mean lesion scores of the left P. RAD were not correlated with right P. RAD while correlations between right and left P. FEM and left and right D. HUM were 0.52 and 0.58 respectively.

Table 20, presents the mineral analysis of the right humerus shaft, comparing means at each killing weight but ignoring breed and treatment. Ash, calcium and phosphorus values and calcium: phosphorus ratio did not differ significantly ($P < 0.05$) when breeds or floors were compared at each killing weight. Ash content of the bone decreased ($P < 0.05$) from 57.2% at 3 days to 55.9% at 43 days (weaning, then increased ($P < 0.05$) at each killing weight to 64.4% at 80 kg and stayed at a similar level of 65.1% and 64.5% at 100 and 120 kg respectively.

Bone calcium was lowest at 3 days (21.8%), 43 days (22.4%) and 20 kg (23.2%), increasing from 24.1% at 40 kg to 26.8% at 80 kg and then declining to 24.6 and 24.2% at 100 and 120 kg, respectively.

Bone phosphorus increased ($P < 0.05$) from 9.3% at 3 days to 11.7% at 20 kg and then remained at about the same level with the exception of pigs at 60 kg which had a lower value of 10.7%.

Calcium: phosphorus ratio changed somewhat with age, being high (2.36) at 3 days, decreasing to 20 kg and increasing to a high of 2.55 at 60 kg, then decreasing in the last three weight groups to 2.10 at 120 kg.

TABLE 20

MEAN CHEMICAL ANALYSIS FOR THE RIGHT HUMERUS SHAFT

	Weight or Age								
	3 Day	Wean	20	40	60	80	100	120	SE
Ash %*	57.2b	55.9a	57.2b	60.9c	63.6d	64.4de	65.1e	64.5e	0.29
Calcium %	21.8a	22.5a	23.2a	24.1b	27.1c	26.8c	24.6b	24.2b	0.22
Phosphorus %	9.3a	10.2b	11.7d	11.1cd	10.7bc	11.2cd	11.4d	11.5d	0.19
Ca/P	2.36c	2.21b	1.99a	2.18b	2.55d	2.39c	2.16b	2.10ab	0.05

*Ash, calcium, and phosphorus are on a dry, defatted basis.

TABLE 21

CORRELATION COEFFICIENTS CALCULATED FOR RELATIONSHIP BETWEEN CARTILAGE LESION SCORES AND BONE MINERALIZATION

	Ash	Calcium	Phosphorus	Ca/P
Left D.HUM	0.18	-0.26	0.11	-0.24
Right D.HUM	0.16	-0.19	0.29*	-0.31
Left P.FEM	0.32*	-0.06	0.27	-0.20
Right P.FEM	0.41	0.19	-0.05	0.17

The bone analysis values in this investigation compared favourably with values considered normal, published by Stockland and Blaylock (1973) and Liptrap et al. (1970). Correlation coefficients, calculated for the relationship between cartilage lesion scores and bone mineral values of the 80, 100, 120 kg groups were low and showed no relationship between the severity of lesions and the bone analyses values.

Shetlar et al. (1958) found elevated globulin and lowered albumin in arthritis caused by chronic erysipelas; Sikes et al (1967) revealed elevated total serum protein in arthritic swine. Correlation coefficients were calculated between lesion scores at left and right D. HUM and P. FEM and several of the blood serum parameters (Table 22) using information from the 80, 100 and 120 kg groups respectively. These three weight groups were chosen because the blood parameter values selected did not differ ($P < 0.05$) between the groups. There were two significant ($P < 0.05$) correlation values between left and right D. HUM and inorganic phosphorus (-0.34 and -0.32, respectively). Lowered BUN was correlated ($P < 0.05$) with increased lesion score at right D. HUM (-0.44). Lowered albumin was correlated ($P < 0.05$) with lesion score at right P. FEM (-0.28) and lowered β-globulin was correlated ($P < 0.01$) with lesion score at left P. FEM. There was a positive correlation of 0.35 ($P < 0.05$) between lesion score at right P. FEM and

TABLE 22

CORRELATION COEFFICIENTS FOR CARTILAGE LESION SCORES

WITH BLOOD SERUM CONSTITUENTS

	Ca	Inorg P	Alk P	BUN	T.Prot	Alb / T.Prot	α Glob / T.Prot	β Glob / T.Prot	γ Glob / T.Prot	LDH	SGOT
LDHUM	0.02	-0.34*	-0.05	-0.17	0.03	0.05	-0.07	-0.01	0.08	-0.21	-0.19
RDHUM	0.18	-0.32*	-0.05	-0.44**	-0.14	-0.01	0.22	-0.18	0.02	0.03	0.12
LPFEM	-0.18	-0.21	0.12	-0.15	-0.15	0.16	-0.02	-0.44**	0.07	-0.07	0.17
RPFEM	-0.22	0.03	0.04	-0.05	0.03	-0.28*	-0.11	0.10	0.36*	0.06	0.17

γ-globulin. These correlations are too few to suggest that there are any relationships between the lesions observed and any infectious agent. The blood parameters measured in this investigation do not suggest that there isany gross metabolic or pathologic changes occurring with the incidence of joint cartilage lesions.

Duthie and Lancaster (1964) and Thurley (1971) reported the highest incidence of mobility difficulty in fast growing swine. Grondalen (1974d) has shown however, that rapid weight gain does not necessarily give a higher incidence and degree of joint lesions. Correlation analysis was done between lesion scores at the left and right D. HUM and P. FEM and average daily gain (Table 23). Results of 80, 100 and 120 kg groups were used separately and then combined to obtain four separate correlation coefficient values for each joint lesion score. Values for the combined groups were generally lower than the values calculated for each group separately even though there was very little difference in growth rate between the groups. Correlation values for each group were not consistent; the 100 kg group having a negative value of -0.58 for right D. HUM with average daily gain and the 120 kg group having a value of +0.50 for the similar comparison. Both values were significant at ($P < 0.05$). The low correlation values for the groups combined appear to be as a result of the lack of agreement between groups for correlation relationships.

TABLE 23

CORRELATION COEFFICIENTS FOR CARTILAGE LESION SCORES WITH AVERAGE DAILY GAIN

	Weight			
	80kg	100kg	120kg	Combined
LD.HUM	-0.25	-0.26	0.47	0.10
RD.HUM	0.13	-0.58*	0.50*	0.15
LP.FEM	0.23	0.51*	0.42	0.38*
RP.FEM	-0.23	0.05	0.36	0.04

It is suggested, from the data in this experiment, that fast growth does not have a direct effect on the severity of cartilage lesions.

There were no breed or floor treatment differences at any of the weight groups in tissue dissection or muscle + fat proximate analysis results. No relationship existed between the muscle + fat to bone ratio so that data is not discussed in the text. Means for tissue dissection and analyses are presented in Appendix Tables 2 and 3.

GENERAL DISCUSSION AND SUMMARY

Exercise, during the growing period, reduced ($P < 0.05$) the severity of leg weakness in boars. Boars exercised at 2 and 4 km/h, three days a week for 60 min each day had fewer ($P < 0.05$) leg abnormalities and better mobility than non-exercised Controls. Front legs were most severly affected in the Controls and were improved more than the hind legs by the imposition of exercise. The severity of arthrosis, as judged by lesion score was not significantly ($P < 0.05$) affected by exercise although boars exercised at 2 km/h tended to have less severe lesions than the Control or 4 km/h groups. It is possible that exercise increased muscular strength which provided better support for the legs of exercised pigs.

Grondalen (1974f) in one experiment found no significant relationship between joint lesions and leg weakness in slaughter pigs, however, in another experiment, pigs slaughtered because of severe leg weakness showed a high incidence of severe degree arthrosis in several joints. Based on the study reported and on previous studies, there appears to be some relationship between cartilage lesions and leg weakness but the extent of the relationship is unclear.

Cartilage lesions were observed most frequently and were the most severe in the distal humerus and the proximal femur. Cartilage lesions occurred less frequently in the proximal humerus and the proximal radius-ulna and severity

of lesions was judged lower than that of lesions in the distal humerus and the proximal femur. Cartilage lesions occurred also in the distal radius-ulna, distal femur, proximal tibia and distal tibia but they were less severe and occurred less often than at the other sites. The characteristics of the lesions were described as illustrated in Plates 1 to 6. It cannot be determined from observation of the lesions whether physial trauma is the cause of the lesions or whether a metabolic deficiency contributes to the problem.

Grondalen (1974e) demonstrated large individual differences in skeletal and joint measurements and he believes that some of the variation in shape and size of the elbow and stifle joints are correlated with the incidence of arthrosis and leg weakness. He suggests that some of the changes in shape put abnormally high pressure on localized areas of the joint and contribute to the development of lesions. No measurements were made in the present experiment to detect changes found by Grondalen and no statement can be made regarding the significance of such changes.

Cartilage lesions of a mild degree were observed in this experiment shortly after weaning, indicating that the condition does occur in the very young pig. There were no consistent differences ($P < 0.05$) between breed or floor treatments in the incidence or severity of cartilage lesions,

suggesting that genetics or physical trauma caused by hard floors are not major factors contributing to arthrosis.

There was good agreement between lesion scores at left and right proximal femur, left and right distal humerus and left and right proximal radius-ulna.

Blood serum chemical profile constituents did not reveal any gross metabolic abnormalities and there were no apparent association between cartilage lesion scores and the concentrations of any of the blood constituents examined. Bone mineralization appeared to be normal and there were no significant relationships between bone analysis results and lesion scores.

Nielsen (1973) and Grondalen (1974d, 1974f) believe that fast growth induced by high level feeding increases the incidence of both leg weakness and cartilage lesions. There was no apparent relationship in the experiment described here between growth rate and the severity of cartilage lesions within weight group. There was however, a significant ($P < 0.05$) increase in incidence and severity of lesions with increasing weights of pigs up to 120 kg, most of the changes occurring between 60 and 120 kg.

The two experiments reported indicate that cartilage lesions occur in pigs that are housed and managed under very different conditions. Boars in the exercise experiment were strictly confined in individual pens except for exercise imposed upon the two exercise groups. In the second experiment,

boars were housed in groups with more floor area per pig than in the first experiment and no effort was made to impose exercise treatments on the pigs.

The experiments reported here do not answer many questions regarding the cause or causes of leg weakness and cartilage lesions of boars. They do indicate that exercise reduces the severity of leg weakness. Cartilage lesions occur early in the life of boars and generally increase in frequency and severity with increasing age and weight. The experiments reported indicate that arthrosis is not caused by fast growth, bone mineral deficiencies, or blood serum metabolite abnormalities. Biochemical and histological studies presently being conducted but not reported here may provide some answers to the cause or causes of arthrosis. Establishing the causes will assist greatly in developing solutions to reduce the problems of leg weakness and arthrosis.

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APPENDIX A

APPENDIX TABLE 1

CORRELATION COEFFICIENTS FOR RELATIONSHIP BETWEEN LESION SCORE OF LEFT D.HUM AND BLOOD SERUM CONSTITUENTS OF BOARS IN EXERCISE EXPERIMENT

Serum Constituent	Left D.HUM
Calcium	-0.02
Inorganic Phosphorus	0.12
Alkaline Phosphatase	0.19
Blood Urea Nitrogen	-0.02
Total Protein	-0.06
Albumin	-0.01
α-Globulin	0.07
β-Globulin	-0.11
γ-Globulin	-0.27
Glucose	-0.06
Cholesterol	-0.06
LDH	0.22
SGOT	0.49

APPENDIX TABLE 2

DISSECTION OF LEFT SIDE OF BOAR CARCASS INTO MUSCLE + FAT AND BONE AT EIGHT WEIGHT GROUPS

	Weight (kg) or Age								
	3 day	Wean	20	40	60	80	100	120	SE
Side Weight (kg)	0.46a	2.2b	6.0c	12.7d	20.6e	28.0f	35.7g	42.6h	0.28
Front Weight (kg)	0.28a	1.2b	3.3c	6.9d	10.9e	14.9f	19.0g	22.6h	0.21
Hind Weight (kg)	0.17a	0.92b	2.7c	5.8d	9.6e	13.1f	16.7g	19.9h	0.15
Front									
Fat + Muscle (kg)	0.13a	0.74b	2.2c	4.94d	8.33e	11.7f	14.8g	17.8h	0.17
Bone (kg)	0.08a	0.30b	0.62c	1.2d	1.5e	1.9f	2.2g	2.5h	0.05
Fat + Muscle (%)	44.1a	58.4b	67.8c	71.5d	76.1e	78.4ef	77.7ef	79.4c	0.82
Bone (%)	27.1g	25.2f	18.8e	16.7d	13.7c	12.3bc	11.7ab	10.1a	0.58
Fat + Muscle (kg)/Bone (kg)	1.7a	2.4b	3.6c	4.3d	5.6e	6.3f	6.8g	7.4h	0.14

APPENDIX TABLE 2 (Continued)

	Weight (kg) or Age								
	3 day	Wean	20	40	60	80	100	120	SE
Hind									
Fat + Muscle (kg)	0.13a	0.55b	1.9c	4.2d	7.4e	10.5f	13.3g	16.0h	0.13
Bone (kg)	0.10a	0.20a	0.43b	0.84c	1.1d	1.3e	1.6f	1.8g	0.04
Fat + Muscle (%)	39.3a	59.8b	69.2c	72.5d	77.3e	80.2f	79.8f	80.5f	0.81
Bone (%)	29.5e	22.3d	16.0c	14.4c	11.5b	10.3ab	9.4a	8.4a	0.69
Fat + Muscle (kg)/Bone(kg)	1.3a	2.7b	4.4c	5.1d	6.9e	7.9f	8.4f	9.2g	0.22

APPENDIX TABLE 3

PROXIMATE ANALYSIS OF MUSCLE + FAT FROM THE LEFT SIDE OF BOARS AT EIGHT WEIGHT GROUPS

	Weight (kg) or Age								
	3 day	Wean	20	40	60	80	100	120	SE
Gross Energy kcal/g	6.05a	6.68b	7.01c	7.43d	7.47d	7.76e	7.91ef	7.96f	0.06
Protein %	67.1f	54.0e	48.7d	40.2c	39.0bc	34.4ab	32.7a	32.0a	1.77
Fat %	26.7a	41.9b	47.1c	56.6d	57.5de	62.3ef	64.8f	65.7f	1.88
Ash %	4.8c	3.0b	2.8b	2.0a	1.9a	1.8a	1.6a	1.6a	0.12
Dry Matter %	22.7a	34.1b	35.6bc	37.7cd	38.3d	44.0e	48.5f	47.7f	0.88